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AGRICULTURAL EXPERIMENT STATION

Bulletin No. 221 December, 1924

THE SMUT DISEASE OF ONIONS

By P. J. Anderson and A. Vincent Osmun

This bulletin records six years' experiments on the control of smut, the most destructive disease of onions in New England and presents practical recommendations based on these experiments. It also includes an account of the origin, history and economic importance of the disease and the development of the causal organism.

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By P. J. Anderson and A. V. Osmun

INTRODUCTION

Commercial onion growing in Massachusetts sixty years ago was confined to the eastern part of the state, centering especially in Essex county about the Danvers section. But continuous cropping brought diminishing yields year by year until the growers found that they could no longer produce a profitable return on onions even in that fertile section. New land must be found, and the industry shifted gradually to the west until now practically all of the Massachusetts domestic supply of surplus onions is produced in the Connecticut Valley. The fertile acres of the Danvers section, famous onion center since colonial days, are no longer planted to onions.

When we inquire into the reasons for the diminishing crops and the westward shifting of the industry we find that the most important contributing factor was the increase in the prevalence and destructiveness of smut until the toll which it took wiped out the profits. A field once thoroughly infested with smut was permanently eliminated from profitable onion growing, and since no method of checking the disease had been discovered at that time, the inevitable result was the migration of the industry from a section so largely planted to onions.

The Connecticut Valley region, however, did not long escape. Year by year, smut became more prevalent; fields were being planted to other crops and the history of Danvers was in a fair way to be repeated along the Connecticut, when the formaldehyde method of controlling smut was discovered and the industry saved for the Valley.

But the formaldehyde method as worked out by the pathologists of twenty years ago was far from satisfactory. The formulas of application which they recommended were cumbersome and the machinery inadequate. The writers were unable to find a single grower in the Connecticut Valley who was applying the formaldehyde according to the rates of dilution and distribution which were recommended by the pathologists. Finding these inconvenient, the practical growers modified them in various ways to suit themselves. The results obtained were more various than the rates of application. Some were successful; many had partial control; others ruined the crop. Lack of uniformly successful results caused many to condemn the method and either to plant the fields to less profitable crops or to omit the formaldehyde and tend the onion crop at a reduced profit or an actual loss.

Such was the situation when the writers began their investigation of onion smut in 1918. The whole field of control seemed ripe for a reworking.

It was necessary that a formula of applying the formaldehyde be determined and standardized for Connecticut Valley conditions, a formula which should be practical for the grower and at the same time could be depended on to control the disease and not cause serious injury to the onions. The machine for application must be improved. The behavior and life-history of the smut fungus throughout the whole year must be carefully studied with the special object of finding a better method of combating the disease. Many other minor problems were yet unsolved.

During the last six years the investigation has been prosecuted in the laboratory and greenhouse during the winter and in the fields of the onion growers of Sunderland, Amherst and Leverett and on the Experiment Station farm during the growing season. It was essential that the field control experiments be continued through a series of years on different farms because it was found that the season and other environmental conditions influenced the results of the treatment and it was desirable to develop a method which would be suitable for every year under a wide range of conditions. The writers believe that after six years of experimenting they are ready to publish definite recommendations. In the present bulletin there are also presented the experiments and data on which the recommendations are based, along with the results of some other accessory lines of investigation on onion smut.

HISTORY OF THE DISEASE

Onion smut is probably a disease of American origin, although its history previous to 1857 is unknown. Onions have been cultivated and used by all the civilized races of the world in all ages. Starting with the inscriptions on the pyramids, there is an enormous amount of ancient and modern literature on all phases of onions and onion culture, but it contains no mention of smut or any trouble which might be interpreted as smut previous to the middle of the 19th century, when it was first found in New England. If smut is of Old World origin, this omission is certainly nothing short of remarkable. Is it not more probable that it occurred in an inconspicuous way on some other closely related American plant and thence passed over to the onion which it found to be a more suitable host? To be sure, we have no published record of its occurrence on any other American plant (except for one record of a wild onion, *Allium Nevadense,* in the Far West); but when one recalls that new diseases and new hosts of disease organisms are being discovered every day, and that it may occur on its wild host plant only as an inconspicuous seedling disease, this does not seem to be a serious objection. The fact that the disease has been found on twenty-six other species of plants of the same genus not previously reported as affected by smut (p. 8) indicates that all of the host plants of the onion smut have not yet been found.

The first published record of the existence of onion smut which the writers have seen is in the Proceedings of the Essex Institute for 1857 (31: 207, 211–214)[*].

Since this interesting article seems to have escaped the notice of other students of the disease[†] and is in a rather inaccessible publication we quote it in full. At a field meeting of the society at Beverly, Mass., on June 24, 1857, a letter was read by the secretary from Mr. J. W. Proctor,[‡] a Danvers farmer. This letter according to the report of the secretary, Mr. Wheatland,

> "treated of the smut of the onion and of a maggot, which attacks that vegetable, threatening serious injury to the onion crops. He considered that at least half the estimated crop of the present season would be lost. This letter was referred to a committee consisting of Messrs. S. P. Fowler, George D. Phippin, and Henry F. King, in order that it might make the necessary investigation, and report on the subject at some subsequent meeting of the Society."

At the next meeting, which was held at Wenham on July 10, 1857, Mr. Geo. D. Phippin of Salem, made the following report on onion smut:

> "As to the second agency found so destructive in the cultivation of the onion your committee report that the smut found growing in the leaves of the onion plant has been examined under the microscope; but the specimens used were so imperfect that no information of a decisive character has been obtained. It is evident that the smut of the onion is a parasitical fungus which originates and develops itself within the cellular tissues of the leaves looking in some stages of growth like the filaments of a Botrytis. It makes its appearance on the first leaf and descends toward the root destroying the texture and rendering the leaf spongy and streaked with a black dust. Perhaps then it may originate from the use of too much putrescent

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[*] Numbers in parenthesis refer to bibliography in the back of this bulletin. Numbers after the colon give the page on which statements referred to may be found.

[†] All the writers on onion smut who have mentioned the matter at all (Farlow, Thaxter, Stone, Walker, Cornu, *et al.*) quote as the first published record, the observation of Ware (51), 12 years later. Probably a more thorough search through the agricultural literature of Essex County just previous to 1857 would reveal earlier allusions to smut.

[‡] Ten years previous to this date Mr. Proctor, who appears to have been an onion grower of considerable prominence, presented "An Essay on the Cultivation of the Onion" before the Essex Agricultural Society (33) in which he gave considerable attention to the pests and enemies of the onion, but no mention is made of smut. The fact that a practical, keen observer like Mr. Proctor had never seen smut leads us to believe that it was not present at that early date in the Danvers section.

> matter in the soil, helped toward development by a peculiar low and damp atmosphere. The use of muscle-bed mud for culture of onions is well known but we have not ascertained whether such manuring is liable to the fly or not. An overmanured soil made so by too much putrescent animal or vegetable matters could be treated with lime ashes or charcoal, which by helping to absorb the ammonia would check the fermentary process so favorable to the growing of fungi of every kind.
>
> "It would be interesting to ascertain whether this particular species of smut is to be found upon the leaves of the wild garlic (*Allium canadense*) for it may be that a more succulent condition of the cultivated plant as in our field onion, may be more susceptible to this disease from the high culture which it obtains. Such parasitic plants destructive to crops, indicate the tendency toward extinction of a particular variety, and the remedy may lie in changing the seed or by inducing some newer form not liable to be thus affected."

The next published record of the disease is in the appendix of the 17th annual report of the Massachusetts Board of Agriculture (51:10) in which is printed an address by Mr. Benjamin P. Ware, a Marblehead farmer, before the Essex Agricultural Society on September 29, 1869. He states that smut is "very destructive, turning the most promising fields . . . to scenes of desolation," and that it "so impregnates the land with its spore as to render it unsafe to plant onions for several years on land thus affected." In view of our present knowledge of the long time required for impregnation of the land, these statements indicate that smut was not a new disease in Essex County in 1869, but that it must have existed for many years. There is evidence according to Thaxter (44:131) that it occurred in Connecticut as early as 1860, although there is no published record. In his report of the U. S. Department of Agriculture for 1869 (7:224) the commissioner, Mr. Horace Capron, devotes a page to onion smut, but mentions no locality except Massachusetts. From this, one judges that it was not known to occur in other states at that time. In the U. S. Commissioner's report for 1872, (43:193) Mr. Thomas Taylor, the microscopist, mentions a field of four acres in Swampscott where the disease was so bad that the field was abandoned. In the same report, he published the first figures of onion smut spores. The first accurate scientific description of the disease and its causal fungus is by Farlow (14:164) in the appendix of the report of the Massachusetts Board of Agriculture for 1876. He states that at that time it was not known to occur anywhere except in Massachusetts and Connecticut and presents convincing evidence that it was of recent origin.

Summing up all the evidence in regard to the origin of smut we may say that in all probability it existed on some native American plant closely related to the onion and first made its appearance on the cultivated species about 1850 in New England.

From New England it has spread to all of the onion-growing regions of the northern United States, but is not known to occur in the southern states. In 1889 it was known to be present in Ohio and Pennsylvania (44:135) and in Vermont (25:141), New Jersey in 1890 (20:352), New York, previous to 1869 (37), Iowa, about 1900, (30:216) and reached the Pacific coast about 1911 (6:187). The date of introduction into other states is not recorded, but at present it is known to occur in Indiana, Illinois, Wisconsin, Missouri, North Dakota, Delaware, Kentucky, Tennessee, West Virginia, Kansas and Minnesota.

It is probable that it spread from America to Europe and other parts of the world. It was reported from near Amiens, France, as early as 1872 (12:40), from southern France in 1877 (34:379) and from the neighborhood of Paris in 1879 (10:51). It is said by Frank (17:186) to have been found the same year in Germany near Leipzig, but Zillig (54:298) questions this since he finds the first official report of its occurrence in Germany in 1909. If it occurred in Germany during the intervening years it must have been very inconspicuous. Zillig (1923) states that in that country it sometimes causes a loss of 60 per cent. of the crop. The first published record of smut in England was in 1919 (13:168) but there is evidence that it occurred in the British Isles as early as 1900 (52:443). Walker (49:15) reported it as common in Holland. It has also been reported from Denmark. The writers were also informed by Dr. Ito of the Sapporo Experiment station that it is not uncommon in Japan. The losses from smut in countries other than America have not usually been considered serious.

LOSSES FROM SMUT

Onion smut has caused—and is now causing—great losses to the onion growers because:

1. Many acres of land best suited for the growing of onions have had to be turned to the growing of other crops because the land was so impregnated with smut that a good crop of onions could no longer be grown.
2. It costs just as much to tend a crop where smut has reduced the stand as it does to tend a full stand but the returns are less. The diminished yield frequently leaves no margin between cost of production and the selling price.
3. The price of chemical, special apparatus and extra labor for application of chemical, where preventive measures are used, must be added to the production cost.

The Plant Disease Survey of the United States Department of Agriculture (32:210) estimated the loss from this disease in the United States in 1918 at 754,000 bushels. In individual fields in Massachusetts losses may vary from 0 to nearly 100 per cent.

At attempt to calculate the losses in dollars would be conditioned by so many modifying factors that it would necessarily be the merest guess and no such attempt will be made by the writers. It is, by all odds, the most important disease of onions occurring in America, and time or money spent in controlling it is well worth while.

SYMPTOMS

The first signs of smut appear on the young seedlings within two or three weeks after the seed are planted. In fact, the very first recognizable indication of disease has been observed here (1:131) within ten days from the date of planting. The cotyledon (or seed leaf) which is the first part to appear above the ground is marked by a slight distortion and swelling instead of being perfectly straight as is the case with a healthy plant. A few days later, when one holds the plant up to the light and looks through it, he sees a dense black, opaque, elongated area (or several of such) inside the seed leaf. Many of these weakened plants "damp off" and fall at this stage. Even if they do not damp off they gradually shrivel and die if the attack is severe. If one crushes these dead cotyledons he finds them filled with a black powder (spores). The heaviest loss in an infested field is during this cotyledon stage; the grower notices that his rows become thinner day by day, until only a fraction of the seedlings which came up remain standing. If, however, the initial attack was not very severe the plants do not die in the cotyledon stage but the successive leaves develop and in many cases are perfectly healthy, the disease having been sloughed off with the cotyledon. But usually smut will appear as long dark streaks in each of the succeeding leaves. Such plants remain stunted and the leaves are short, brittle, and distorted (Fig. 1A). They continue to die in various stages of development throughout the summer. Very few of them develop bulbs of any size. Even if they continue to live until time of harvesting, they are never stored because in the last stages they develop "bottom rot" and are thrown out. As the diseased plants grow larger, the black smut pustules (or lesions) also increase in size. They may be several inches long or extend throughout the entire length of the leaf. As the leaf becomes old and dried these lesions split open and the spores fall out (Fig. 1A). Frequently they rupture to the inside of the hollow leaf. On the bulb itself, the pustules are raised and appear gray as one looks at the black mass through the white covering of the scales (Fig. 1B). When the outer scales die the black spores fall out into the soil (Fig. 1). The appearance of a row of diseased onions as compared with a row of healthy onions is shown in Fig. 2.

THE CAUSE OF SMUT

Smut is produced by the growth inside the tissues of the onion of a parasitic fungus of the order Ustilaginales. The spores of this fungus were first distinguished and figured by Taylor in 1872 (43:193 and Fig. 29), but the first accurate description is by W. G. Farlow of Harvard University in 1876 (14:175). C. C. Frost of Brattleboro, Vt., had previously examined it and found that it belonged to the smut genus,

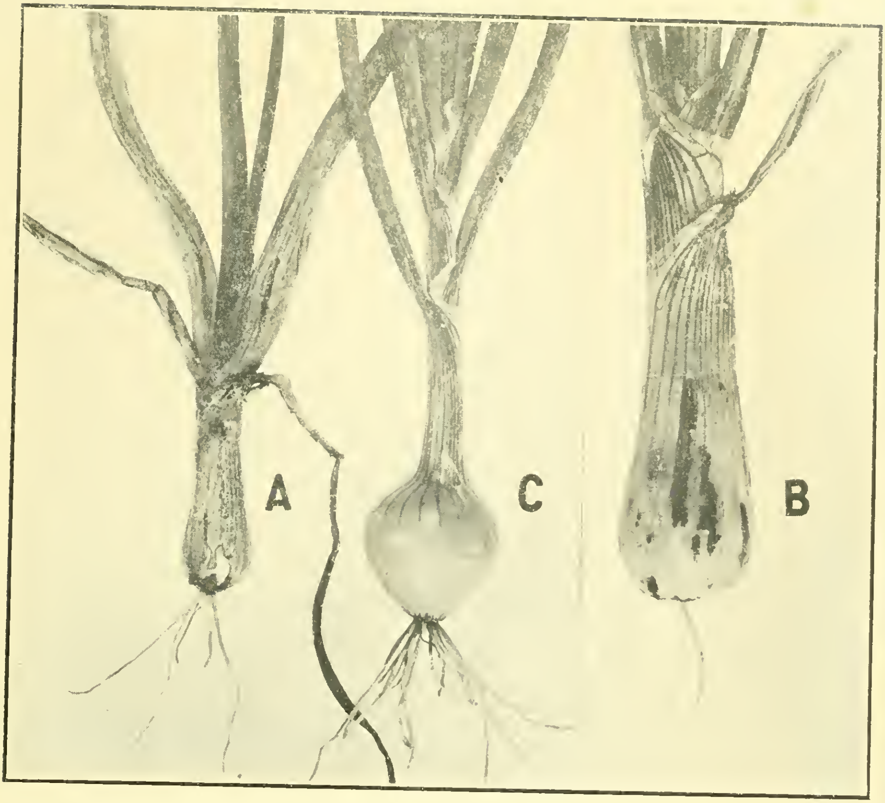

Fig 1.—Symptoms of smut on mature onions. A. Showing distorted leaves with ruptured pustules exposing black spore powder. B. Smut pustules on bulb. C. Healthy onion for comparison. Note failure of diseased plants to develop normal bulbs.

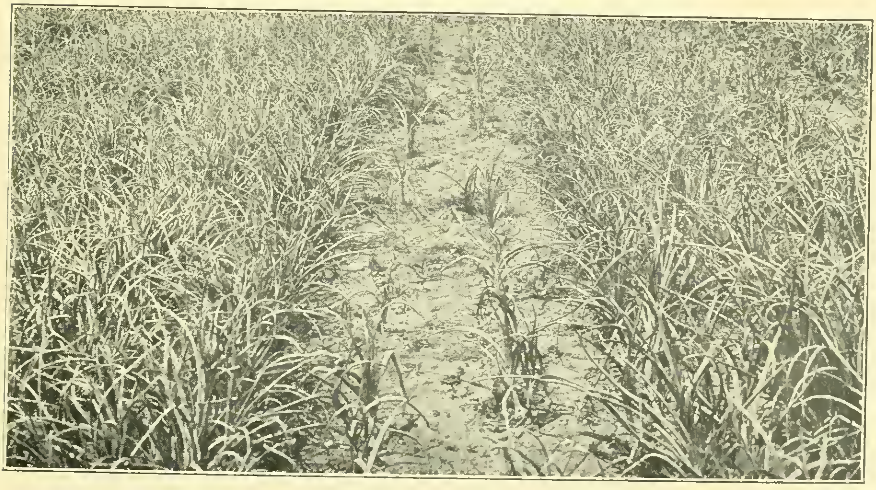

Fig. 2.—Formaldehyde treatment for smut. 2 rows in center received no formaldehyde.

Urocystis, and had sent some specimens to Farlow with the appended name *Urocystis cepulae* (*cepulae* means *of the little onion*). Farlow adopted Frost's name and published a description but indicated Frost as the author of the species (although the latter apparently never made a description). Some of the European writers (*e.g.* Cornu and Frank) quote Farlow as the author. It is usually referred to as *Urocystis cepulae* Frost.

Shortly after Farlow described this as a new species there was considerable discussion among students of fungi as to whether this really was a new species or whether it was identical with some previously described smut. No smut fungus had been described previously from the cultivated onions but some had been described from wild species of the same genus and from closely related genera of the Liliaceae. Thus *Urocystis magica* was described from Italy on *Allium magicum.* Farlow, in his second paper (15:114) expresses the opinion that *U. cepulae* is identical with *U. magica* Pass. Another closely related smut is *U. Colchici* Schlecht which occurs on *Allium rotundum* and a number of species of the Liliaceae outside the genus Allium. Farlow pointed out the differences between *U. Colchici* and *U. cepulae* and considered them as distinct. Cooke (9:634) however, considers the difference insufficient for specific rank and calls the onion fungus *U. Colchici var. cepulae.* Magnus (28:348) also considered *U. cepulae* as distinct from *U. Colchici.* Schroeter and Winter (Die Pilze, p. 121, 1884) would unite all the above species under *U. Colchici.* Magnus and Cornu agree with Farlow in keeping the two distinct. Clinton in his monograph of the North American Ustilagineae (8:451) says, "There has been some discussion whether the American species is distinct from *Urocystis Colchici* and *Urocystis magica* of Europe, the latter species also occurring on species of Allium. The three while very closely related are distinct. The species described here (*U. cepulae*) differs from both in having smaller spores and spore balls and also from *U. Colchici* by rarely having more than one spore in a ball." Another species of Urocystis on Allium is *U. Allii* (Belham) Schellenberg on *Allium subhirsutum.* The writers have not examined this species, but both Liro and Schellenburg regard it as distinct from *U. cepulae.* Inoculation experiments by Anderson showed *A. subhirsutum* to be one of the few species of Allium which are immune to *U. cepulae.*

Liro (27) has recently merged the genus Urocystis with the older genus Tuburcinia because he was unable to distinguish any morphological differences between them and has proposed the name *Tuburcinia cepulae* (Fr.) Liro as the correct name for the onion pathogene. This change has been adopted by European writers but as yet has not appeared in American literature. In both of these genera, the spore —more commonly called the "spore ball"—is not a single cell but is composed of a globose ball of a number of cells permanently bound together. In Tuburcinia all of these cells are fertile, *i.e.* capable of germination, while in Urocystis only the central ones are fertile while the peripheral ones are sterile and called accessory cells. In opposition to this usual conception Liro maintains that no such distinction exists, but that in all these species there is a covering layer of sterile cells. When Fries erected the genus Tuburcinia, the first species which he placed under it was *T. Orobanches,* the spore ball of which is composed of 1-3 larger central cells surrounded by a compact layer of smaller, flatter cells. Contrary to the opinion of most previous students of this genus, Liro considers the smaller outer cells as the sterile accessory cells and therefore, that this spore ball differs from that of ordinary species of Urocystis in no way. From examination of slides of Fries' original specimen kindly furnished by Dr. Liro, the writers were able to confirm Liro's conclusions in regard to the relative size of the cells; but it should be kept in mind that the separation of the genera is not based on differences in size of central and peripheral cells but on their ability to germinate. Microscopic examination of these slides did not disclose any difference in the outer cells which would prevent germination. Brefeld (Untersuch. A.D. Gesammtg. d. Myk. Heft. 12:180 and Pl. XI. 1895) has published excellent figures of the germination of the spores of *Tuburcinia primulicola,* a species very similar to *T. Orobanches,* and he shows the peripheral cells germinating in large numbers. He was unable to find any sterile cells outside of those which germinated. Liro does not mention any germination studies and there is no record in the literature that the germination of the spores of *T. Orobanches* has been observed. Until the germination of these spores has been studied, and until there is some concord of opinion among mycologists as to the constancy of the sterile layer of covering cells, we prefer to retain for the onion smut organism the name which has been in continuous use for the last fifty years.

The true onion smut fungus *U. cepulae* Frost, does occur, however, on other species of Allium. Clinton (8:451) reported it on specimens of *A. Nevadense* from Nevada. In England the disease is said to be more severe on leeks (*A. Porrum*) than on onions (13:170) and was reported from France on this host as early as 1881 (29:277). Quite recently (55:57) Zillig has reported that he was able to infect *A. fistulosum* L., *A. globosum* Red., *A. odorum* L. and *A. Porrum* L.

One of the writers, before he was aware that Zillig was working on the same problem in Germany, began a series of inoculations by planting seed of all obtainable species in soil which was very heavily infested with *U. cepulae.* Records taken every week after the plants came up gave the total percentage and severity of smut infection for each species. A full description of these experiments and the results are published elsewhere (4). Briefly, it was found that out of 39 species which were tested, 8 proved to be immune to smut, while 31 showed varying degrees of susceptibility. Thirteen species were just as susceptible as the common onion in that the disease affected them in just the same way throughout the season. In five others it caused heavy mortality in the cotyledon stage but did not persist throughout the season. In 13 others the cotyledons were sometimes affected, but the plants rarely if ever died from the effects of smut. These results lead us to believe that if the numerous other species—there are some 250 species in the genus—were tested in the same way, a large proportion of those which reproduce by seeds would be found to be susceptible. (Many species escape the disease by reproducing only by bulblets.)

Within the species *Allium Cepa*, the cultivated onion, there are numerous varieties, but up to the present there are no data or observations to indicate that any of them show any degree of resistance to smut. It has been stated at various times, however, that the white varieties are somewhat more susceptible than the red or yellow ones. Walker and Jones (50:236) tested several varieties, and Whitehead (52:449) tested 21 varieties of onions and 11 varieties of leeks (*A. Porrum*) but none was found which showed resistance. Anderson (4) tested 54 varieties of cultivated onions but found no significant indication of resistance among them.

*Morphology and Life-History of the Smut Fungus**

If one examines microscopically the dusty black mass from the leaves or bulbs, mentioned above, he will find that each particle of dust is a spore (chlamydospore) of the fungus which causes smut. It is a compound spore composed of one large central brown cell, to the surface of which are attached 15–40 smaller hemispherical cells (see Fig. 3A). The dark central cell is the fertile cell, while the numerous smaller surrounding cells, which are transparent, but with a brownish tint, are the sterile cells (pseudospores or accessory cells).

The spores get into the soil either by the rupturing of the sorus (pustule) or by decay of the infected part of the onion which has fallen to the ground. In the soil they may germinate at once or after a few weeks or months, or they may remain for years before germination occurs. In either case they grow into long slender branching tubes (the mycelium) and in a favorable soil this growth may be sustained for many years even though onions are not planted again on the same field. The mycelium does not produce other spores (*sporidia* or *conidia*) but it may break up into short pieces which are able to lie dormant for long periods and then germinate on the return of favorable conditions. The soil becomes so infested with spores, mycelium and these detached mycelial segments that without preventive measures onions can no longer be raised on it.

Method of germination of the spores. In a previous publication Anderson (1:108) has described the process of germination as it occurs during the first few months after maturity of the spores. Briefly it is this: A globose hyaline body, at first no larger than one of the sterile cells but later becoming as large as the fertile cell, develops on the surface of the fertile cell (Fig. 3B). From this body one to eight germ tubes grow out (Fig.

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*In a previous publication from this station (1) the reader will find more detailed information on the full life history of *Urocystis cepulae.* In the present publication the seasonal life-cycle is outlined very briefly.

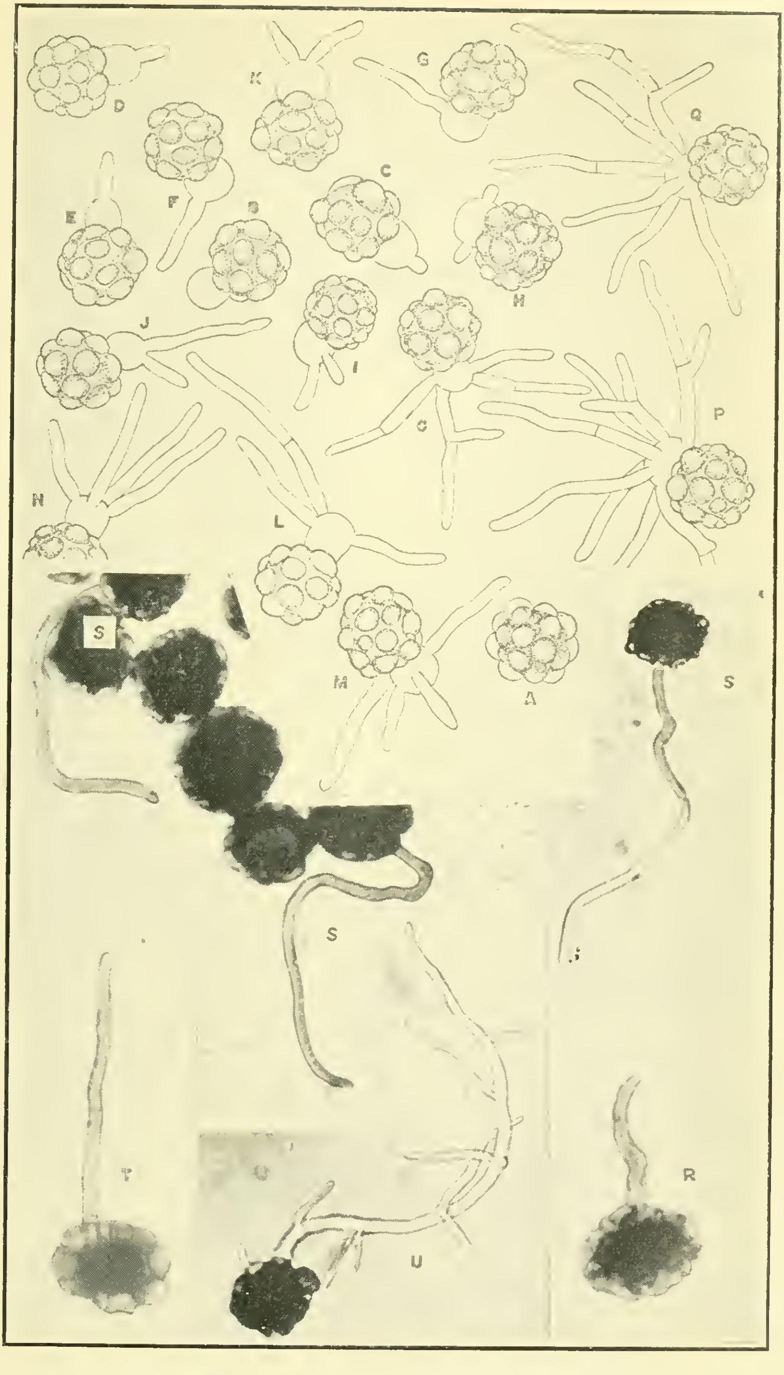

Fig. 3. Germination of onion smut spores. A. A fresh spore before germination. B-Q. Successively older stages of germination of spores three months after maturity. Camera lucida drawings. R-U. Successive stages in the germination of spores after ripened in soil for three years. Photomicrographs.

3C-Q) and by elongation, branching and septation form a dense mycelium without any indication of sporidia. Subsequent to the publication of these results, smutted leaves were placed in damp soil in test tubes where they were kept for three years. At the expiration of that time the spores were again tested for germination by the same method as was used in the previously reported tests. The process of germination was now found to be quite different from that which took place during the first three months after maturity. Most of the sterile cells had now collapsed and no longer presented the plump appearance which they have on fresh spores. Germination began within 2-5 days after the spores were sowed on the cold agar plates. The first striking difference was that there was no large globose body developed on the face of the fertile cell, but a single slender tube grew out directly from the central cell (Fig. 3R-U). Occasionally two tubes seemed to come from the same place, but the second one may have been merely a branch of the first arising very close to the surface of the spore. Usually the germ tube remained simple and unbranched until it had reached a length of 20–30 times the diameter of the spore. Then it became septate and branched sparingly. The protoplasm disappeared from the older cells but remained dense in the advancing tip cells. No sporidia were observed at any time even when the further development was examined daily until masses of mycelium a half-inch or more in diameter were formed. All the further development and behavior of the mycelium was the same as previously described after the germination of the spores according to the first process. The process of germination of these "after-ripened" spores is very similar to that described by Thaxter (44:142) and Whitehead (53) except that both of them found sporidia. The difference in germination between fresh spores and after-ripened spores is susceptible of various interpretations, but none will be attempted until after further investigations have been made.

It is commonly stated in the literature on onion smut that the chlamydospores live for many years—any number up to 25 may be found—in the soil and then germinate to infect the seedlings when onions are again planted. Such statements are erroneously based on the observation that smut recurs on a certain piece of land which has not been planted to onions for that particular number of years. It seems more probable that the smut is carried through those years in the form of mycelium living on the organic matter in the soil. Another possibility is that the spores or other organs of the fungus may have been washed or carried in some other way from fields where onions had been grown in the interim. During the season of 1923 smut occurred in destructive form on a plot of land on the experiment station farm which, as the records showed, had not been planted to onions in at least 40 years, but this plot was adjacent to another field where onions had been grown during many years. A similar case is reported by Whitehead (52:444). There are numerous ways in which it could be spread from one field to another, *e.g.*, by surface washing, wind, tools, animals, direct spread of the mycelium, workmen, etc.

From the soil the mycelium enters the very young seedlings by boring directly through the epidermis. Infection may occur only during a very limited period while the epidermis is tender. The exact length of this period was determined by Walker and Jones (50:238) and by Anderson (1:120). Walker and Jones found that "the plants became immune . . . between the nineteenth and twenty-fourth days after sowing, when the cotyledon had about attained its full growth and as the first leaf was emerging." Anderson found that they were no longer susceptible after the 17th day under greenhouse conditions, but that "the period of susceptibility is not limited by the number of days during which the seeds have been in the soil, but by the length of time required for the seedling to pass through certain stages of development" and that "susceptibility begins to diminish from the time that the knees emerge from the ground and little if any infection occurs after the first leaf has emerged from the side of the cotyledon." Thus the conclusions from these two investigations—carried out at the same time, but entirely independently, were identical—that all infection occurs before the first leaf is developed—a period which may be roughly stated as 3 weeks after planting. Walker and Jones very ingeniously demonstrated that immunity after this period depends on the maturity of the tissues of the cotyledon or the successively developed leaves each of which in turn forms a protective sheath about the base of the next developing leaf.

As soon as the infecting mycelium has passed through the epidermis of the cotyledon, it spreads rapidly in all directions, deriving its food from the cells of the young onion. After growing for a period of 5–10 days the mycelium forms dense knarls between the cells of the host plant and then the knarls are transformed into masses of black spores which have been previously described. It must not be understood, however, that the mycelium from a single point of infection grows throughout the whole length of the cotyledon. On the contrary, a single mycelium probably never extends more than a quarter of an inch from the point of infection and the ripe sorus is developed at that point. If there are a number of sori in the cotyledon—which is usually the case—they are the result of the same number of separate infections. Very long sori in the cotyledon are the result of anastomosing shorter sori.

Just at the junction of the young cotyledon and the first root there is a slight swelling known as the root joint. Immediately above this is the growing point,—a region of less than a half inch,—from which place all new leaves start. This point remains stationary throughout the further development of the onion bulb. If an infection occurs near the growing point the mycelium reaches this rapidly dividing tissue and as each leaf grows up it carries with it some of the infecting mycelium which spreads and sporulates in the leaves. When an onion once becomes infected in the growing point, it never recovers. If, however, the cotyledon is infected only in the upper part the mycelium does not reach the growing tissues and the disease is sloughed off with the cotyledon and the plant develops normally.

RELATION TO ENVIRONMENTAL FACTORS

Most plant diseases vary greatly in prevalence and severity according to the season. Certain kinds of weather favor them, others retard them. They ruin the crop one year and are entirely absent during other years. Onion smut, however, differs from most common diseases in this respect: It is about the same every year. Some growers think they find it more severe during a dry year; just as many others think a wet year favors it. The writers have had occasion to watch the course of the disease for many years but have never noticed any marked difference in its severity from year to year on the same field. Walker and Jones (50:240) conducted controlled experiments in the greenhouse to determine the effect of variation in the moisture of the soil on the percentage of smut infection and concluded "that soil moisture does not function as a factor limiting infection with onion smut within the limits at either extreme where good germination and growth of the host occur."

A similar experiment was conducted by the writers at the Massachusetts Experiment Station in which the seedlings were grown in pots of naturally infested soil kept at moisture contents at intervals of 2 per cent. from 12 to 40 per cent. of the dry weight of the soil. Below 12 per cent. this soil was too dry for good germination, while at the upper limit it began to decline rapidly from 34 per cent. Within this range the smut loss was almost total. Above 34 per cent. there was a decline in the percentage of infection, but the soil was very muddy and it is not likely that any grower would plant onion seed in soil so wet as this. It is conceivable, however, that rains immediately following the planting might keep the ground so wet that infection would be reduced, but probably the loss of germination on account of wet soil would more than counterbalance the gain from decreased infection. The practically identical results of these two experiments conducted independently in Wisconsin and Massachusetts indicate that the moisture condition of the soil in the spring is without influence on prevalence of the disease during that year.

Neither is there any indication that a warm spring in the Connecticut Valley is any more or less favorable than a cold one. All the onions here are planted in the early spring before the soil becomes very warm. Walker and Jones (50:247) conducted experiments on the effect of soil temperature on infection and concluded "that a high percentage of infection may be expected up to 25° C. (=77° F.) above which there is a rather abrupt reduction, leading to complete inhibition at 29° C. (=84° F.). There appears to be no lower limit of temperature for infection within the range where onion seeds will germinate and normal growth occur." They explain the absence of smut from the southern onion regions, *e.g.*, Texas and Louisiana, as due to the fact that in those regions the seed is planted in late summer when the soil temperature is too high for infection to occur.

The temperature experiments of Walker and Jones were also duplicated at the Massachusetts Experiment Station and the results were practically the same. Onion seed germinated at all temperatures between 8° and 35°C., but the percentage drops off rapidly above 27° and is much retarded below 13°. It required 33 days for the plants at 8° to show above the surface of the soil. The optimum is between 15° and 27°. Smut was not entirely absent at any temperature tried, but the percentage dropped off suddenly and rapidly above 27°. Below 27° there were no significant differences at any temperature. There seems to be no lower limit of infection within the range of germination of the onion seeds. This suggests the possibility that smut might be avoided or diminished by delaying the planting here until the soil became warm. Late planting, however, is not conducive to good crops in the Connecticut Valley and, in addition, this method has been tried (50:237) here without any beneficial effect.

It is apparent from the results of the experiments just mentioned that the only soil temperatures which could influence prevalence of smut would be from 27°C. (81°F.) upward. Does the soil of the Connecticut Valley onion region ever approach such high temperatures during the infection period, *i.e.*, approximately during April and May? We have no local continuous seasonal records for the soil, but since all infection occurs within the upper inch of soil we may approximate it from the air temperature records during those months. The soil temperature during the heat of the day, to be sure, may rise several degrees above that of the air, but we may allow a latitude of ten degrees or more and still reach some conclusion. Weather records at Amherst for the ten-year period 1915–24 show the mean hourly temperature for the month of April to be 45.8°F. and for May, 56.5°F. Even though the soil temperature in parts of the field were 20° higher than that of the air —which is beyond reasonable limits for any length of time—it would still not be high enough to limit infection. As far as Massachusetts is concerned then, soil temperature seems to be as unimportant as soil moisture.

We may conclude, therefore, that variations in weather conditions are without effect on the severity of smut infection. There is, on the contrary, very good evidence that certain soil factors may have a deciding influence. A survey of the Connecticut Valley region shows that fields are very unevenly infested. Onions always suffer most in certain fields. In the same field, certain spots are very heavily infested while other parts of the field suffer little. The location of these spots remains approximately the same year after year although the whole field is planted to onions each year and the treatment of all is the same. Such a condition cannot result from any lack of opportunity for the fungus to spread. It can apparently mean only that there is some soil factor which is right for the growth of or infection by the fungus in that part and not in the other parts of the field. Investigation with the object of determining this factor (or factors) is now in progress at this station, but it has not progressed to the point where any conclusions can be drawn.

PREVENTION OF SMUT

When the ravages of smut first began to attract attention of New England onion growers (1850–75), it was thought to be connected in some way with the character of manures applied to the soil, guano being held especially responsible. Remedies were therefore sought through change of fertilizers. Thus Horace Capron (7:224) suggests: "A remedy for this disease must be sought by using less manure, or manures which are less stimulating and afford less nitrogen for the fungus to feed upon. Alkaline manures are very destructive to the fungus. Wood ashes, lime, gypsum and seaweed are very efficacious."

Taylor (43:195), who first made a study of the spores and laid stress on their presence in the soil as a means of carrying the disease over winter and spreading it about, recommended that they be destroyed and the disease thus controlled, by burning heaps of dry weeds and rubbish on the infested fields. This recommendation was repeated by various writers during the next fifteen years, but it does not appear from the literature that anybody tried it. Walker (47:6) has recently recommended burning the onion tops after harvest and the avoidance of returning onion refuse to the soil.

Farlow (14:174) was the first to suggest rotation of crops as a means of control. He was led to believe from the statements of growers that the spores do not live in the soil more than four years and thought that if a smut-infested field were planted to other crops for four years, it would then raise a smut-free crop of onions. He did not think that the spores were carried by wind and in order to prevent the carrying of spores to uninfested fields, he recommended thorough cleaning of all tools which had been used on smut-infested land. Thaxter (44:138) on the other hand, finds that a badly infested crop of onions was grown on a field which had not been planted to onions for twelve years. Sirrine and Stewart (37:149) find in regard to the value of crop rotation: "it is the common experience of onion growers that even an occasional change of the crops for one or two years gives appreciable relief; and it is our belief that a systematic rotation of crops would very considerably reduce the amount of loss from smut." Farlow was also the first to recommend that all smutted onions be pulled during the growing season while the crop is being weeded, and that they be removed from the field and burned. It is not recorded in literature that this method was tried by any grower.

The first accurate experiments of any value on control are those of Thaxter (44:146) who was at that time mycologist of the Connecticut Agricultural Experiment Station. He applied various dry chemicals to the soil in the drills to see whether any of them would prevent infection of the seedlings by the fungus. The chemicals used were copper sulfate, iron sulfate, sodium sulfide, potassium sulfide, potassium chloride, calcium chloride, sodium hyposulfite and flowers of sulfur. Air slaked lime was tried also in combination with some of them. The mixture of air slaked lime and flowers of sulfur gave a fair percentage of control. The others injured the germinating seeds, or were of little or no value in preventing smut, or their use was impracticable. He repeated the experiments the following year (45:103) and again was able to increase by a ratio of about 5:1 the number of onions which could be raised on badly infested land, by the use of flowers of sulfur. Thaxter, himself, however, was not very enthusiastic in his recommendation of the method and two years later his successor, Sturgis (41:14) writes concerning it: "It seems probable now that the measure of success attending this treatment will hardly warrant its extended adoption."

The sulfur-lime treatment was thoroughly tested by Sirrine and Stewart (37:152), their field experiments extending over a period of five years. As a result of all their experiments they conclude (37:145) "that the yield of onions on smutty land may be greatly increased by the application of 100 pounds of sulphur and 50 pounds of air-slaked lime per acre in the drills at the time of sowing the seed. In several instances the yield has been increased at the rate of more than 15,000 pounds per acre as compared with untreated plats. Sulphur alone has considerable value as a preventive of smut, but seems more efficient when mixed with lime. The sulphur and lime should not be applied broadcast as they appear to have no effect on the smut when applied in that way. The sulphur-lime treatment is recommended whenever the loss from smut is as much as one-third of the crop."

Thaxter (44:146) found that infection occurred only in the very young seedling stage. Thus, when the plants were started in sterile soil and then transplanted to the field, they never suffered from smut. Sturgis (42:176) made extensive field tests of this method and demonstrated that it was an absolute preventive of smut. It was also recommended by Sirrine and Stewart (37:145). This most effective of all methods of control has not been adopted by onion growers in general because the amount of labor and time required for transplanting is so great as to render it impracticable where onions are grown on a large scale.

Burying of the surface soil has been tried with some success, but the labor involved is excessive (37:149).

The use of larger quantities of seed on smut infested land has been tried (37:149) but as pointed out by Sirrine and Stewart "there comes a time when it is impossible to obtain a stand no matter how much seed is used." Such a method is also impractical on a field which is unevenly infested, because the onions are too thick on lightly infested parts of the field and laborious thinning is necessitated.

In 1900 Selby (35:76) began experiments in Ohio, using the lime and sulfur treatment as recommended by Thaxter, various other chemicals, quick lime and formaldehyde. After the first year's experiments (1900) he abandoned all but the formaldehyde and the quick lime since they alone gave promising results. All the experiments were on seed sowed very thickly (about 40 pounds per acre) for the production of sets. During the second year he used only the quick lime and the formaldehyde or a combination of the two and obtained a considerable degree of control. In regard to his method of application we quote from his summary (36:51).

"To apply formalin, use at rate of one pound commercial formalin in 25–30 gallons of water (1 oz. to 1½–2 gals.) and apply with drip attachment on seed drill at rate of 500–700 gallons of solution per acre for onion set seeding (about ⅕-¼ as much for field onions) or apply with sprinkler upon the scattered seeds until well moistened, then cover with earth promptly.

"Apply ground quick lime or stone lime, better the former, at the rate of 75 to 125 bushels per acre just before seeding, on the freshly prepared soil. If applied by drill, harrowing will not be required; if broadcast, harrowing should precede planting."

Stone (39) recommended formaldehyde at the rate of 1 lb. to 30 gals. (1–240) or 1 oz. to a gal. of water (1–128). With the improved tank which he describes in detail he found that about 1200 ft. of drill could be treated with one gallon of the solution.

Within recent years all other methods except the application of formaldehyde have been abandoned, since this has given good results and is the most convenient. Various concentrations of the solution and quantities per acre or given length of row have been recommended. The most recent and thorough investigations have been those in Wisconsin by Walker (47). After experiments of several years' duration he recommended the use of formaldehyde* at a dilution of 1–128 applied at the rate of 200 gallons per acre, or one gallon to about 185 feet of drill (1–128–2960, or approximately equal to our 1–128–3000 formula).

In England, Whitehead (52:444) recently made control experiments in which he treated the seed with various percentages of sulfuric acid and with paraform, other experiments in which the soil was treated with soot and salt, paraform, bleaching powder, lime, nitrate of soda, sulfur and lime, calcium cyanamide, carbon bisulfide and formaldehyde. In the summary of the work he recommends only formaldehyde.

We may briefly summarize the methods of control which have been recommended in the past and their present status:

1. Modification of the fertilization of the land has been of no avail. We do not believe, however, that the possibilities of this field of investigation have been exhausted.
2. Removal or destruction of diseased onions or refuse is wasted time.
3. Rotation of crops is of little, if any, value because of the length of time during which the fungus lives in the soil and because of the facility with which it may be introduced from neighboring fields. It is also not economically practicable on high-priced onion land.
4. Search for resistant varieties has yielded nothing up to the present, but should be continued.
5. Burying the surface soil is too expensive to merit consideration.
6. Sterilization of the entire field by heat or chemicals is also too expensive.
7. The use of larger quantities of seed is ineffective.
8. The use of transplanted seedlings is an absolute preventive, but such a method of culture is considered too laborious by growers of the Connecticut Valley region.
9. The use of sets is just as sure a preventive. This is being practiced more extensively every year, not only because of the smut situation but also because of less damage from thrips and of larger yields. The early harvesting of the crop, however, has distinct disadvantages from the storing and marketing standpoint.
10. Chemicals other than formaldehyde have proved worthless, injurious, or at best, very much inferior to that chemical. Sulfur and lime have given the most promise, but are no longer used.
11. The use of formaldehyde is the only treatment which is now recommended or extensively used. The principal objections to the formaldehyde method are—
    (1) the use of large quantities of water which greatly increases the labor at planting time, and
    (2) danger of injury to the seed.

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*Walker also tried (48:323) the sulphur and lime method described by Sirrine and Stewart but found it inferior to the formaldehyde method "both as to efficiency in controlling the disease and ease of proper application."

It was with the object of reducing these difficulties to the practical minimum that field experiments were undertaken by this station. The problem was to find a formula of application* in which the water should be reduced to the lowest possible amount, but without serious damage to the germinating seeds.

The Cowls Farm Experiment, 1919

This experiment was located on a field so heavily infested with smut that the loss was almost complete during the preceding year. Three formulas were used, 1–64–3200, 1–96–3200 and 1–128–3200. The rows were 150 feet long, two untreated rows alternating with each plot of four treated rows and the whole series in triplicate, thus giving a total of 1800 feet of row treated according to each formula. Plots were planted on April 22. The soil was fairly moist when planted; there was only a slight precipitation during the next week, but the month of May was very rainy. No difference between the rows was apparent when they first came up but within a short time the treated rows looked greener and were thicker because of the dying of the smutted plants in the untreated rows. This dwindling continued throughout the summer as more of the smutted onions died and disappeared. On June 2, the number of onions in measured lengths of the rows was counted. Also the percentage of smut among those standing was determined. From an inspection of these data (Table I) it is apparent that there had been a large shrinkage from smut before that date and that half, at least, of those still standing in the untreated rows were smutted. Smut was not eliminated from the treated rows but it was so reduced in amount that the rows were too thick for the growing of bulbs of good size. During August thrips did serious injury, causing the tops to die prematurely. The bulbs on the check rows were much larger than on the treated rows because, after most of the seedlings died, they were far apart and had thus opportunity to grow larger. Very few of the diseased onions were still standing at harvest time and most of them were rotted at the base. Only rarely did one attain a diameter of one inch. The number of sound bulbs in each row was counted as they were pulled. After they had dried for a few days, each plot was also weighed separately. The data is summarized in Table I (p. 27). The comparative yields of treated and untreated rows are also shown in Fig. 4. The difference between the results secured by any of the three formulas is not large. Any of the three shows a gain of over 250 bags (100 lbs. in a bag) per acre. The control secured by the use of any one of the formulas was satisfactory.

If one prefers to measure the efficiency of the treatment by the gain in pounds, the 1–96 formula was somewhat the best. If, however, he wishes to consider the *number* of healthy onions at harvest time as the basis of comparison, the 1–128 formula is somewhat better.†

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*Formaldehyde (*i.e.* the 32–40 per cent. solution of the gas in water) cannot be applied in the concentrated form to the seeds in the row because even a very small quantity prevents the seeds from germinating. It is therefore necessary to dilute it with water. The first question to be answered then is: how much should it be diluted? This is the first variable in the experiments but this variable depends in turn on a second variable viz. the rate at which the diluted solution is to be applied to the row. For example, a 1–50 dilution is excellent if a gallon of it is applied to 700 feet of row but disastrous when applied to 200 feet and worthless when applied to 1400 feet. The numerical expression of these two variables is called the "formula of application." For all of our experiments it is written in terms of pints of formaldehyde—pints of water—feet of onion row. To illustrate: the formula 1–50–3000 means one pint of formaldehyde is diluted to 50 pints with water and the 50 pints of diluted solution applied to 3000 feet of onion row. Thus the first and second figures express the rate of dilution while the second and third figures express the rate of application of the diluted solution to the row in terms of pints of solution and feet of row. In the literature on onion smut control the rate of application is commonly expressed as so many gallons per acre of onions. This is undesirable because we do not treat acres but rows, *i.e.*, the amount of solution should be proportionate to the number of feet of row and not to the area of the field. The number of feet of row in an acre varies according to the distance between the rows. Different growers plant the rows at different intervals. Even in the restricted area of the Connecticut Valley one may find fields of onions planted at 12, 13, 14 or 15 inches and none of them is uncommon. In other sections of the country under different methods of culture other intervals are used. In order that results obtained at one place may be compared with those from another, it is desirable that formulas be expressed according to length of row treated and not acres. It should also be kept in mind that a direct comparison cannot be made between the results of the use of two formulas in which both variables are fluctuating at the same time: One must remain constant while the other is being changed.

†*Methods of calculating the results*: The writers have given considerable thought and attention to the question of the most accurate method of calculating and comparing the results obtained by the use of the different formulas of application. The methods which we have tried—most of which are in use by other investigators—are:

1. By counting the number of smutted seedlings when they are *in the cotyledon stage.* This method is

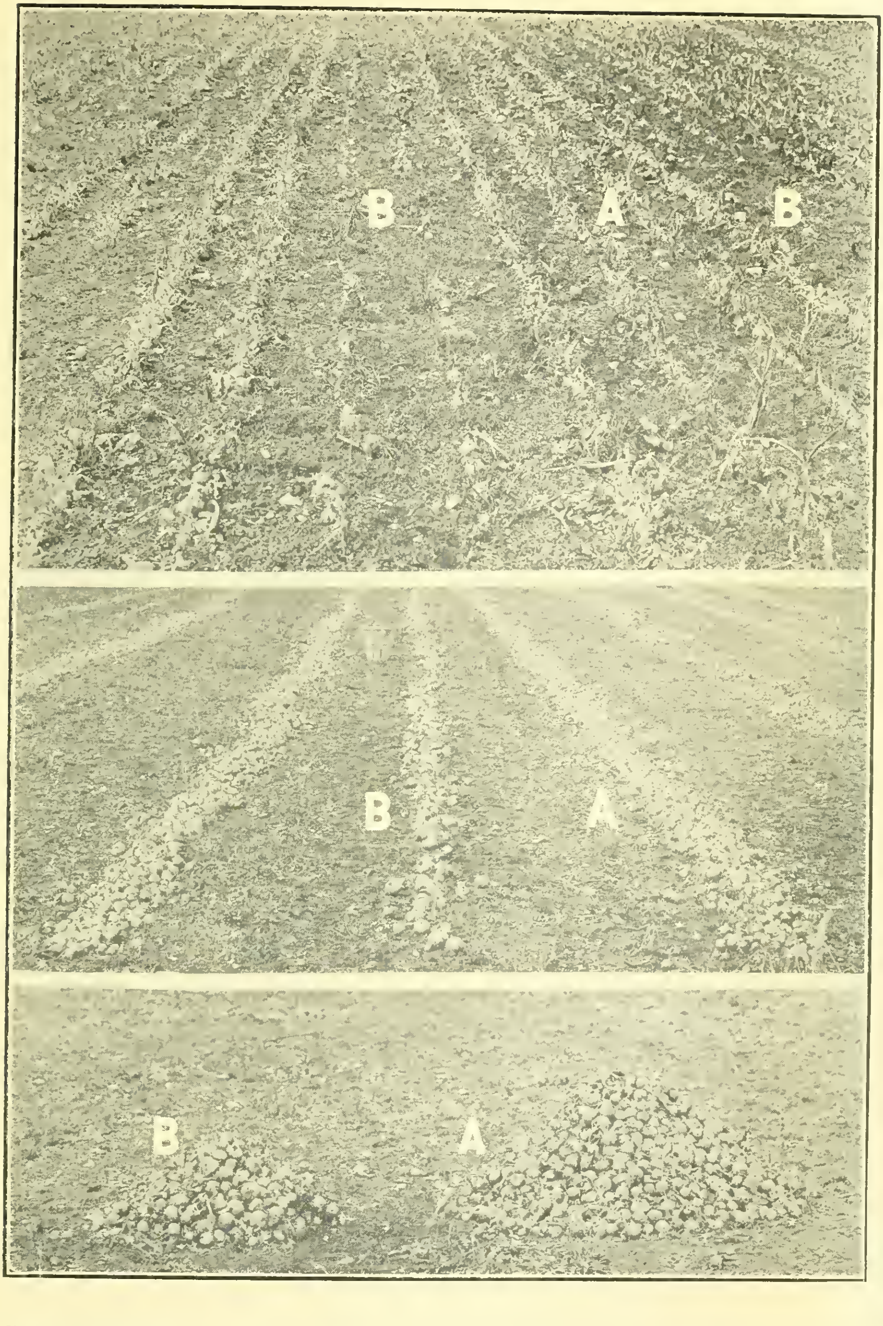

Fig. 4.—Formaldehyde treatment for smut. Yield from 4 treated rows (A), compared with 4 untreated rows (B).

Station Farm Experiment, 1919

The experiment on the Cowls farm was duplicated as regards treatments, but on a smaller scale, on a badly infested plot on the Station farm.

The check rows gradually dwindled throughout the summer while the stand on the treated rows remained excellent. No differences between the results obtained by the use of any of the three formulas could be observed. Through a mistake, the onions of this plot were harvested in the absence of the writers and final data on yield were not obtained. Unquestionably, however, they would have paralleled the yield data for the Cowls farm.

Greenhouse Experiments, 1919–20

During the winter a greenhouse bench 4 x 16 feet was filled with soil from a badly infested field. Three crops of onions, raised in succession, were treated with formaldehyde of different formulas. Commercial formaldehyde was applied at the rate of one pint to 2400, 2800, 3000 and 3200 feet of row. Dilutions from 1–8 up to 1–128 were used. Without presenting all the data, we may state the tentative conclusions at which we arrived as a basis for the field experiments of the following year:

1. The percentage of control was not appreciably greater when one pint of commercial formaldehyde was applied to 2400 or 2800 feet of row than when applied to 3000 or 3200 feet.
2. Concentrated formulas such as 1–48–2400, 1–32–2800 and stronger cause serious injury and cannot be used.
3. The most important indication of the series was that within wide limits, the amount of dilution is not a factor of any great importance *as far as control of smut is concerned.*

C. A. Clark Farm Experiment, 1920

This experiment was on land in Sunderland where onions had been grown for 40 or 50 years. The soil, however, was not as thoroughly infested as that on the Cowls farm used during the previous season. The part selected for experiment included 30 rows, 267 feet long, 12 inches apart, seeded at the rate of 7 pounds per acre. The plots were seeded May 3, the soil at that time being wet and heavy after a backward

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inaccurate because it makes no distinction between those which are badly affected and will die and those which are slightly affected and may produce good onions. Also we have found that it is impossible to distinguish all the diseased plants because many of the lesions are below the surface of the soil.

2. By counting the percentage of smutted plants among those which are standing at some definite period *in the early summer, but after the cotyledon stage.* This was done in the Cowls farm experiment just described and is commonly used by other workers on onion smut. This method is worthless because it does not count those which have already died from the disease and disappeared. We have repeatedly noted that seedlings begin to die within three weeks after planting and the mortality is then heavy for a few weeks. When a young plant dies it shrivels and decomposes so quickly that no trace of it can be found after a very few days. Obviously such plants cannot be taken into consideration in calculating by this method

3. By removing and counting the plants *as fast as they succumb to smut.* This requires a thorough inspection about twice a week for a period of some four weeks, after which all diseased plants may be pulled since it is certain that they will not recover. This is certainly the most accurate method, but under field conditions involves so much labor that it is precluded. We have, however, used it in greenhouse experiments with satisfaction.

4. By counting and comparing the number of *healthy* bulbs in the row at harvest time or shortly before. This does not assume that all onions which have disappeared from the rows during the summer have succumbed to smut, but that all other agencies which would destroy the plants previous to this time would operate equally on all the rows. Therefore, the benefit derived by the grower can be determined by direct comparison of the figures thus obtained. From the experimenter's standpoint it is not quite satisfactory because it does not take into consideration the number of plants which were prevented from germinating on account of the use of formaldehyde of a certain formula. In the experiments of the last season we have determined the amount of such injury by comparing the number of plants which came up and then computing the control on the basis of those which remain. This fourth method has been used throughout the experiments here as being the most nearly accurate practical method of comparing the results obtained by a given treatment.

5 By comparing the *yield of onions in pounds or bushels.* This method is inaccurate because, as every onion grower has observed, the onions in a thin row (such as they are when thinned by smut) being further apart, are larger than in a thick row; therefore, bulb for bulb, are heavier. This difference, however, represents the gain in weight secured by growing bulbs further apart, and in no case could be interpreted as having any relation to the application of formaldehyde. If larger bulbs are desired, the result could be much more economically obtained by planting a smaller quantity of seed per acre while using the formaldehyde. This fifth method was used by the writers during the field experiments of 1919 and 1920 and the final weights are included in the tables, but they should not be considered as accurately gauging the results of the experiments.

spring. Also it rained within 24 hours after the seed was planted and the entire season was rainy.

The formulas used in this experiment require a few words of explanation. Since there was considerable smut in the treated rows during 1919 it was thought best to cut down the distance treated with one pint of the commercial formaldehyde from 3200 to 3000 feet. This also had the advantage of being approximately the same rate of application as was being used in the other states; therefore, our results could be more readily compared. The formulas 1–48–3000 and 1–32–3000 were added to see whether a more concentrated solution would give better control without injury under field conditions. In order to test the effect of increasing the length of row treated with one pint of commercial formaldehyde, the formulas 1–50–4000 and 1–50–5000 were added. From the standpoint of the growers, the 1–50 dilution is the most convenient because most of them use 50 gallon barrels for drawing the water and they all have gallon jugs or cans. It is, therefore, a simple matter to add a gallon of the commercial solution to each barrel of water.

Observations on the course of the disease throughout the summer coincided with those of the previous season. The percentage of smutted plants was not counted during the growing season for reasons previously stated. All the onions were pulled and counted on September 4. A week later they were topped and weighed. The data taken are recorded in Table II (p. 27).

In interpreting the results of this experiment the fact that the soil was very wet at the time of planting must be taken into consideration. The important influence which this factor exerted was understood only after the experiments of later years. We may draw the following conclusions from the data presented in Table II:

1. The highest percentage of control was secured by the use of the concentrated solutions: thus, the 1–64–3000 was the best*, but not much better than 1–32–3000 and 1–96–3000.

2. No advantage was gained by the extreme dilution and use of the large amount of water required for the 1–128–3000 formula. Three of the other formulas gave better control and others were not much inferior.

3. The decided drop in the percentage of control secured by the 1–50–5000 formula indicates that (during a wet spring) the amount of formaldehyde was insufficient. It resulted in a fair amount of control—40 per cent. increase over the untreated plots—but much below the benefit secured by the use of more formaldehyde per acre. The 1–50–4000 formula gave good control, but the yield was not quite so high as for some of the others.

The poor showing made by the 1–48–3000 formula is unexplainable in view of the good showing of the formulas just above and just below it.

The Kuzmeski Farm Experiment, 1920

The field on which this experiment was located is in Leverett and was seriously infested only in spots. The seed was planted May 3, the soil moisture conditions being about the same as previously noted for the Clark farm. Only two formulas were used, viz., the 1–96–3000 formula which approximated the formula which gave the best control during the preceding season, and the 1–50–5000 formula previously mentioned in the account of the C. A. Clark farm experiment. Eight rows, each 436 feet long, 13 inches apart, were treated with each formula, and four rows were left untreated as a check. Data for this experiment are recorded in Table III (p.27).

The results shown in the table confirm the conclusion from the Clark farm experiment that the use of one pint of formaldehyde to 5000 feet of drill is insufficient for the control of smut during a wet spring. Entirely satisfactory control was obtained by the use of the 1–96–3000 formula.

C. A. Clark Farm Experiment, 1921

The experiment of 1920 on this field was practically duplicated during the season of 1921 but with the addition of some more concentrated formulas. The soil, however, was dry and there was no rain for at least two days after the seed was sowed on April 13. The weather continued cold and the seed came up very poorly. When it did come up there was a striking difference between the treated and untreated rows. The checks were much thicker and appeared so throughout the season. There was a very obvious injury from the formaldehyde, irrespective of the formula used. The writers were informed by onion growers who were in a position to know the facts of the case, that growers all through the section had the same trouble with formaldehyde during 1921 and that many fields of onions were plowed under because of the reduced stand.

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*In this connection, it may be noted that Walker (48:324) during two years out of his four years' experiments secured his highest yields by the use of the 1–64 dilution, while during the third year, it was such a close second to the 1–128 dilution that the difference was almost negligible. Despite these results, he recommended the 1–128 dilution.

No yield data were taken in 1921 because the onions were harvested by mistake in the absence of the writers and no records were kept.

After the experience of 1921 it was decided that further progress in the search for the best formula could not be made until the factors which cause formaldehyde to injure were determined. The investigation of this problem was not finished until 1922, but since it has an improtant bearing on the subsequent experiments, we shall consider the findings at this time.

Formaldehyde Injury

At first it was thought that the injury of 1921 was due to some difference in the composition of the chemical. Samples from all available sources were therefore collected, including among them samples of the same material which we had used during the previous years and which had not caused injury. Chemical analyses of the samples by Dr. Holland of the Chemistry department, revealed no differences in composition which were of sufficient size or character to warrant a suspicion of their toxic effect. The manufacturers assured us that there had been no change in the method of manufacture of formaldehyde. The most apparent difference was in the percentage of methyl alcohol contained in the various samples. The sixteen samples were next tested simultaneously on onion seed sowed in greenhouse benches, using for each the formulas 1–50–5000, 1–50–3000, 1–100–3000 and leaving untreated rows between the plots. In order to see what effect variation in the percentage of methyl alcohol would have, samples containing known percentages from 0.4 per cent. to 16 per cent. alcohol were included in the tests. Without discussing the results in detail, they may be briefly stated as follows:—

1. The source of the formaldehyde was without influence on the percentage of plants which came up.
2. Variation in the percentage of methyl alcohol made no difference.
3. With all samples and every formula used, formaldehyde *retarded* germination for a day or two and
4. With all samples and formulas, formaldehyde *prevented* the germination of a certain percentage of the seed, this loss being more apparent when a more concentrated solution was used or where the quantity of the solution was increased.

The results of these experiments eliminated the possibility that the losses of 1921 were referable to difference in the character of the formaldehyde.

Since there had been no differences in the formulas or method of application of formaldehyde nor in the treatment of the soil in 1921, there appeared to remain only the character of the season itself as a possible explanation of the trouble. The character of the spring weather could obviously affect the soil—where the injury occurs—in two ways: (1) in the percentage of moisture and (2) in the temperature. Experiments were undertaken with the object of determining to what extent the percentage of injury is influenced by variation in the percentage of moisture in the soil. The effect of the soil temperature on injury has not been determined as yet.

These experiments have been described in detail in a previous publication (2). For our present purpose it will be sufficient to quote from the summary of that paper:

"When a concentrated formula like 1–50–3000 is used, the amount of injury depends on the moisture condition of the soil. Injury varies inversely as the percentage of moisture.

The amount of injury may be reduced by diminishing the amount of the solution applied per unit of row, but the percentage of smut control is probably also reduced.

The amount of injury in a dry soil may be reduced by increasing the dilution of the formaldehyde without at the same time reducing the actual amount of formaldehyde per unit of row.

The amount of injury can be predicted from the moisture condition of the soil on the day of planting. It is not affected by weather conditions during the subsequent days.

The grower could save time and labor by changing his formula according to the soil condition at the time of planting.

More seed should be applied when formaldehyde is used."

The final results of the formaldehyde injury investigation were not available before the experiments of 1922 were started. Hence the soil moisture and the percentage of loss from formaldehyde injury were not determined.

C. A. Clark Farm Experiment, 1922

The experiment was repeated on the same field during 1922. Twenty-six rows 500 feet long, 12 inches apart were sowed at the rate of six pounds of seed per acre on April 26. The soil was dry and no rain fell during the next week which was windy, cool and dry. Different samples of formaldehyde were tried in which the percentage of methyl alcohol was extremely small (4 per cent.) or very high (16 per cent.). Also comparative tests were repeated with the 1–128–3000, 1–64–3000, 1–50–5000, and 1–50–4000. Formaldehyde injury was evident when the seed came up but unfortunately no records of its comparative extent or of the soil moisture conditions were made. The onions were harvested on August 25. The yield data are recorded in Table IV (p. 28). It will be noted from this table that the results are quite different from those obtained in 1920 on the same field (cf. Table II). The highest yields were secured with the dilute formula, 1–128–3000, while in 1920 it was the concentrated formulas, 1–32–3000 and 1–64–3000, which gave the highest yields. In 1920, the 1–50–5000 gave the lowest yield while in 1922 it was next to the best. This difference can be easily explained, however, in view of the difference in the moisture conditions of the soil at seeding time. The low yields obtained by the concentrated formulas like 1–50–3000 in 1922 were due to reduction of the stand through formaldehyde injury when the soil was very dry. They do not indicate a lack of control because, when less formaldehyde was used (1–50–5000) the yield was increased.

As to the effect of the methyl alcohol, the data show a much larger yield through the use of formaldehyde with a low percentage of methyl alcohol. Up to the present, however, the writers have not had opportunity to repeat this test and would hesitate to draw any conclusions from the results obtained on these two rows during one season.

Kuzmeski Farm Experiment, 1922

This was on the same field as was used in 1920. On April 25 when the seed was sowed the soil was very dry and continued so for the next week or more. The experiment included 16 rows, 220 feet long, 13 inches apart, seeded at rate of four pounds per acre. The observations throughout the summer coincided with those made on the C. A. Clark farm the same season. Smut was serious only in spots; therefore, the harvest data do not really show how complete was the control (since all the onions in the entire row were counted and therefore considerable stretches of row where there was little smut to control were included). In the worst places hardly any onions remained standing in the check row while there was a normal number in the treated rows. Only one dilution was used on this field but it was applied to the row at three different rates. The final results (presented in Table V (p. 28) confirm the conclusions drawn from the C. A. Clark farm experiment of the same year; viz., that the largest yield is obtained by using the 1–50–5000 formula, during a season when the seed must be sowed in a dry soil. The difference is due to formaldehyde injury and not to lack of control of smut.

The Objects of the Field Tests of 1923

Differences in yields secured by the various formulas in 1922 were the results of variation in (1) the control of smut and (2) the number of seeds prevented from germinating by the formaldehyde. The presence of these two variables made the interpretation of the yields very uncertain. An effort was made in the experiments of 1923 to determine to what extent each of these factors was responsible for the variation in yield. This was accomplished by first determining the extent of the chemical injury. During the third or fourth week after planting, when it was thought that practically all the plants which would come up were visible and before any of them had disappeared from smut or damping off, the number of plants in each row was determined irrespective of whether they were diseased or not. Comparison of these with the untreated rows determined the extent of the chemical loss. The relative amount of loss from smut was determined at harvesting by subtracting the number of sound bulbs from the number of seedlings which escaped chemical injury. It is not thereby assumed that all the plants which died in the interim were killed by smut but that other agencies acted equally on all the rows. Also in order to check up under field conditions the influence of soil moisture at planting time, the percentage of moisture in the soil one inch below the surface was calculated for each experimental field on the day of planting.

Allen Clark Farm Experiment, 1923

This experiment was located in North Amherst on land heavily infested with smut at one end but very lightly at the other. It included 28 rows, 283 feet long, 13 inches apart, seeded at the rate of six pounds per acre. The ground was fairly moist, containing 17 per cent. water with a retentive capacity of 65 per cent. of the dry weight. It was planted on April 27 and there were heavy rains on the 28th and 29th. The rain probably came soon enough to affect the results of the treatment. Inspections while the onions were coming up and comparison by counting the seedlings at the end of a month showed the chemical injury to be negligible in this field. On September 4, when the onions were ready to harvest, the sound bulbs in 100 feet of each row on the more heavily infested end of the field were counted. The results, presented in Table VI (p. 28) are about what might be expected when the soil was neither extremely dry nor extremely wet. The highest yields were secured with the formulas of medium dilution (1-64-3000, 1-75-3000) or where the rate of distribution was medium (1-50-4000). None of the formulas failed to control, but the 1-50-5000 was least satisfactory. The appearance of the field four weeks before harvesting is shown in Fig. 2.

Kuzmeski Farm Experiment, 1923

This experiment was on the same field as the experiments of 1920 and 1922. It consisted of 24 rows, 436 feet long and 13 inches apart, seeded at the rate of six pounds per acre on April 21. The soil was extremely dry and dusty. A high wind during the day and the succeeding days kept the upper layer in the same condition for a week. The moisture was 6 per cent. and the retentive capacity 45 per cent. of the dry weight of the soil. All conditions were ideal for a high percentage of formaldehyde injury.

Examination when the onions were coming up and counting the number of seedlings when it was judged that all had come up, showed that the injury was certainly all that was predicted. On September 3 the number of sound bulbs remaining were counted. The data on this experiment are summarized in Table VII (p. 29). These data show that there was severe injury with all formulas used. The 1-50-5000 formula caused the least loss but that was 20 per cent. Even when the solution was diluted 1-100 there was a loss of 36 per cent. It is doubtful whether any practical formula can be used under these very dry conditions which will eliminate this loss. Under these conditions it is probably best to use the 1-50-5000 formula and increase the amount of seed enough to offset the formaldehyde injury.

Station Farm Experiment, 1923

This was the same field on which the experiment of 1919 was located. It consisted of 40 rows, 12 inches apart and 75 feet long, seeded on April 26 at rate of six pounds per acre. The soil was very dry and remained so for 48 hours after planting.

The moisture was 12 per cent. and the retentive capacity 64 per cent. of the dry weight. Such a condition was favorable for a high percentage of formaldehyde injury and when the onions came up the injury was apparent. The percentage of chemical loss was determined on June 1 and the yield data were taken on August 30. The data, presented in Table VIII (p. 29) show that the highest gain was obtained by the use of the 1–50–5000 formula and the next by the 1–64–3000 formula. The injury caused by the 1–50–3000 formula was so severe that there was an ultimate loss even though smut was controlled very effectively. On such a soil the 1–50–5000 formula is undoubtedly the best.

Conclusions from all of the Formaldehyde Experiments

After five years of experimentation, the writers came to some fairly definite conclusions in regard to the control of onion smut with formaldehyde. These conclusions, which will now be briefly stated, are supported by the data which have just been presented.

1. Smut can be controlled in any field in the Connecticut Valley and during any season by the use of a formaldehyde solution.
2. Extreme dilutions such as one part of formaldehyde in 128 parts of water, involving the use of a large amount of water, extra labor and inconvenience, are not necessary under the conditions which prevail here.
3. Within fairly wide limits, the control of smut is not dependent on the dilution, but on the actual amount of formaldehyde applied per unit distance of row. Thus, the concentration is not limited by lack of control, but by danger of injury to the seeds.
4. Any formula for the application of formaldehyde which is strong enough to control smut, also causes a certain percentage of the seeds to fail to germinate. This injury is especially noticed when the soil is very dry at planting time.
5. Formaldehyde injury varies inversely with the moisture content of the soil, and directly as the concentration of the solution and the amount of such solution applied per unit length of row.
6. The grower may reduce the loss from formaldehyde to a very small percentage and at the same time get better control of smut by changing his formula of application according to the moisture conditions of the soil on the day when the seed is planted.
7. From the standpoints of (a) profitable (but not necessarily maximum) prevention of smut, (b) minimizing the labor of drawing water, (c) ease of mixing the solution, (d) maximum reduction of the weight of water which must be carried on the drill, and (e) avoidance of severe chemical injury, we recommend the following as the most practical method of application:

   If the soil is very dry, use the 1–50–5000 formula; if fairly moist, the 1–50–4000, and if wet, the 1–50–3000 formula.

   Or this might be expressed to the grower thus:

   Put one gallon of formaldehyde into a 50-gallon barrel and fill to the top with water. If soil is very dry, apply at rate of one barrel to one acre of onions (13 inches apart). If the soil is medium moist, apply 1¼ barrels, and if wet and heavy, 1⅔ barrels per acre.
8. On a dry soil the amount of seed per acre should be increased.

The Formaldehyde Tank for the Onion Drill

The formaldehyde solution is applied to the row from a tank attached to the seeder. Various kinds of tanks and methods of regulating the flow of the solution from them have been used and described by previous investigators (5:161).

In order that the control of smut be effective and injury reduced to the minimum it is important (1) that the rate of flow be uniform and (2) that the operator have some means of knowing just how much solution he is applying. These two requirements were doubly important for our experimental work.

In order that the data obtained might be reliable, a machine was needed which would distribute evenly and with a fairly high degree of accuracy any desired quantity of solution on a stated length of row. For this purpose the regulating apparatus on all of the machines which have been described before was found to be worth-

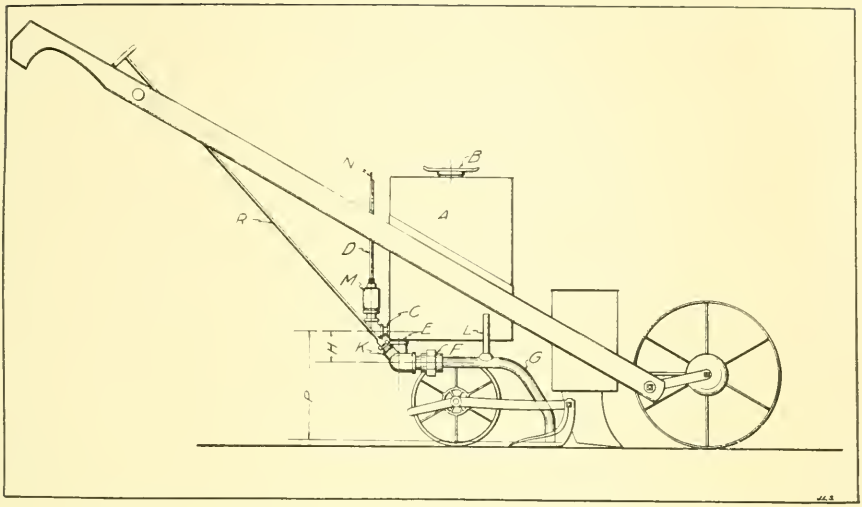
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Fig. 5.—Mechanical drawing showing details of formaldehyde tank construction.

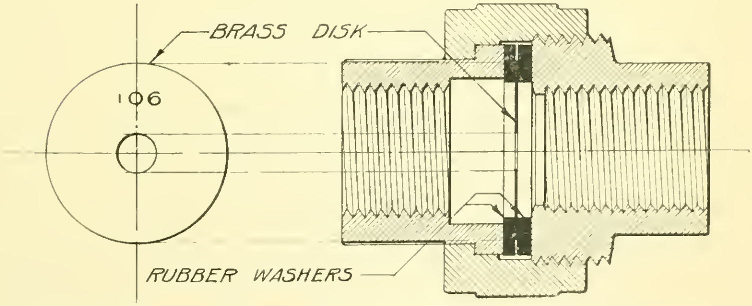
BRASS DISK
106
RUBBER WASHERS

Fig. 6.—Sectional view of union in outlet pipe, with disk and washers in place.

less. None had a valve which could be set so that the operator would know when he started across the field how much solution would be applied per hundred feet. Actual tests of the different types of tanks showed considerable variation in the flow depending on how full the tank was. A 14-quart tank described below required more than twice as long to deliver the last quart as it did the first. The one-gallon copper tank first constructed by Stone (Mass. Agr. Expt. Sta. Circ. 21) — which is still in the possession of the Station—was tested and showed a difference in time of 15 per cent. between the first and last point. None of the tanks previously described has any method of correcting this error. None of them has any provision for eliminating the error due to variation in the speed of the operator. In short, there were so many sources of error and variation in all of the machines described up to the present that they were found to be utterly unsuitable for accurate research studies and a new tank and method of regulation had to be devised. The one which was finally evolved after experimenting with many different modifications is illustrated in Fig. 5 and described below.*

The tank itself (Fig. 5A) is a 14-quart cubical galvanized iron box attached between the handles of the drill just back of the seed box. The bottom of the tank is not flat but has a slight slope to a lowest point at the rear from which the solution is conducted through a ½-inch pipe (E) to the stopcock (K) and to the union (F). From there it is led through a ⅜-inch flexible block tin tube (G) and distributed on the seed and soil just back of the seed spout and in front of the coverers. The valve (K) is operated by a ¼-inch iron rod (R) from the rear end of the handles. It has nothing to do with the regulation of the flow but merely starts or stops the stream at the ends of the row or wherever desired.

The rate of flow from the tank is regulated by a series of brass disks with central apertures of graded sizes. A disk is held in place between rubber washers in the union of the outlet pipe (Fig. 6). Any number of these simple brass disks may be quickly cut out with tin shears from a sheet of brass. A hole is drilled through the center of each disk and this is enlarged with a rat-tail file to the proper size for the delivery of a gallon of solution in the previously calculated number of seconds which the operator wishes to use. The number of seconds required to deliver a gallon of solution is then stamped on the disk (Fig. 6). The size of the aperture needed depends on the formula of application which the operator wishes to use and the rate at which he walks. The number of disks which the experimenter or grower needs depends on the number of formulas he wishes to use, and the number of men, of different speeds of walking, who expect to push his drill. In our own experimental work seven different formulas of application were being tested and the drill was pushed at different times by three operators, the first one walking 4 feet per second, the second one 4½ feet per second and the third one 5 feet per second. Thus before the experiments were completed there were 21 disks. The operator could quickly find the proper disk by reference to a table attached to the side of the tank (Table 1).

TABLE 1.

Indicating the Disks of the Onion Drill to be Used According to the Speed of Workman and Formula Desired

Formula	4 Ft. per Sec.	4½ Ft. per Sec.	5 Ft. per Sec.
1- 50-3000	120	106	96
1- 50-4000	160	142	128
1- 50-5000	200	178	160
1- 32-3000	188	167	150
1- 32-4000	250	222	200
1- 64-3000	94	83	75
1-128-3000	47	42	37.5

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*The authors are glad to acknowledge the very helpful cooperation of Professor C. I. Gunness and Professor J. L. Strahan of the Department of Rural Engineering, whose aid in the solving of some of the mechanical difficulties and the preparation of mechanical drawings, has been invaluable.

To illustrate: If the operator found that he walked at the rate of 4½ feet per second and he wished to use the 1–64–3000 formula, a glance at the table would tell him to insert in the union the disk stamped with the figure 83. Such a large number of disks will be needed only by the experimenter. The practical grower would not have occasion to use more than two or three and could make them as desired. This method of regulation was found to be very satisfactory and has the advantages of (1) permanent accuracy; no variation with wear or play; (2) cheapness and ease of construction within the reach of any grower; (3) simplicity; no complicated mechanism to be frequently out of repair; and (4) great elasticity, since a disk may be quickly made to suit any desired rate of flow.

The next modification was made for the purpose of correcting the variation in flow due to difference in head of the liquid as the quantity in the tank diminishes. All of the tanks which the writers have seen described have loose-fitting lids in the top through which the solution is poured to fill the tank. As the solution flows out through the outlet pipe the space which it leaves in the tank is immediately filled with air which comes in around the lid. Such an arrangement makes the rate of flow entirely dependent on the height of the water in the tank and as a result, the flow is much more rapid when the tank is full than when it is nearly empty. In order to determine the extent of such variation, the 14-quart tank just described was filled and the water permitted to run out with the lid loose or removed entirely. The time required for delivering each of the successive quarts was determined with a stop watch and the average of three tests is indicated in Table 2:

TABLE 2.

Rate of Flow of Each Successive Quart of Liquid from 14-Quart Tank (Open)

Quart	Seconds	Quart	Seconds
1	17.7	8	24.3
2	18.8	9	25.2
3	19.2	10	26.9
4	20.0	11	29.3
5	20.5	12	32.3
6	21.6	13	34.6
7	22.8	14	39.4

Thus, the operator who started with a full tank would be putting on the first part of the treated row double the amount which he put on the last part. The resulting control or injury would naturally show a similar variation. Data derived from the use of such a tank cannot be accurate. The variation in even the small tank described by Stone has been noted above. In order to make our control data reliable it was absolutely essential that this variation be eliminated. After considerable experimentation this was finally very successfully accomplished by modifying the tank thus: Instead of a loose-fitting lid, a screw cap (B), of 2-inch diameter (such as is commonly used on an automobile radiator) is used for closing the opening in the top. When screwed down with the shoulder against a rubber washer, this makes the top air-tight. A stand-pipe (D) parallel with and as high as the side of the tank is connected with the air vent (C) by means of an elbow.*

In this way, atmospheric pressure is maintained at the level of the vent (C) and consequently a uniform flow of solution is obtained irrespective of the height of water in the tank. The effective head producing the flow is always equal to (H). In order to prove that the flow is uniform, the outflow of each successive quart was timed just as described above but with the air-tight cap screwed down, and (with the No. 150 disk in the union) every quart from the first to the 14th flowed out in just 37½ seconds.

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*In a later model this stand-pipe is built inside the tank and is simpler in construction but the principle is the same.

Two other modifications of minor importance have been added. In the enlarged base of the stand-pipe there is a float (M), which consists of a light hollow brass cylinder which has a "play" up and down of one inch. Attached to the top of this float is a slender brass wire stem (N) passing up through the narrow part of the stand-pipe and projecting an inch above the top of it when the float is up, just even with the top when the float is down. When the stream is running from the tank and everything is in order, the float is down and the stem does not appear above the top. If, however, there is any leak in the top of the tank or the operator has forgotten to screw down the cap, *i.e.*, if the tank for any reason is not air-tight, the water rises in the stand-pipe to the level in the tank, the float remains up and the projecting stem warns the operator that something is wrong. The float is thus a safety device and not an absolutely essential part.

The second modification is a very small pipe (L) about two inches long inserted on the upper side of the outlet pipe. This was added when it was discovered that for each of certain intermediate disks there were two distinct rates of flow. If the pipe below the union became immediately filled with water when the stream was turned on, it continued to come out in a steady stream and we had the faster rate of flow. Under these conditions the effective head would be (P) in the diagram. But at other times, even with the same disk, air gained access to this pipe and the water dribbled out. Then we had the slow rate of flow due to the head (H). Either flow remained constant but one never knew when he opened the valve which speed he would have. This difference in flow was eliminated when air was admitted to the outlet pipe through the small opening and pipe just mentioned.

With this improved tank just described all chances of error due to variation are eliminated except one. Variation in the rate of application might arise from variation in the speed at which the workman pushes the drill; *e.g.*, he might walk more slowly when he was tired or in softer land, etc. Numerous tests of the speed of different workmen at various times have convinced the writers, however, that a man's speed is remarkably constant and the error from this source is small. Nevertheless, it would be a distinct improvement if even this small error could be eliminated and the practical grower would be saved the trouble of measuring his speed and calculating the disk which he should use. This could be done if the apparatus were so constructed that the amount of solution delivered was proportionate to the distance travelled (*i.e.*, to the number of revolutions of the drill wheel) and not dependent on the length of time during which the valve is open. Then the rate of application would be entirely independent of the speed at which the drill was pushed. Such a regulating apparatus, geared to the drill wheel, is mechanically possible and its construction has been planned at various times by the writers. The construction has been abandoned for various reasons but principally because it would be too complicated and expensive and therefore less suitable for the average onion grower. For all practical purposes, and even for a fairly high degree of accuracy for experimental work, the apparatus described above is quite satisfactory.

MATERIALS OTHER THAN FORMALDEHYDE

One objection to the use of formaldehyde is the danger of injury to the seed under certain soil conditions which have been discussed previously. Although this can be largely avoided by changing the formula of application to suit the soil condition, growers cannot always be depended on to attend to this and some losses from this source are inevitable. It would be much better if we had a substitute which would give just as good control as formaldehyde, but without the attendant seed injury. In a search for such a substitute the writers have experimented with a list of chemical preparations, including Kalimat, Pythal, Furfural, Semesan, Uspulun, Germisan and several disinfecting powders manufactured by the Du Pont Company and by the Corona Chemical Division of the Pittsburgh Plate Glass Company. All of these were found to have some merit in decreasing the amount of smut, but for the most part the control was inferior to that secured by formaldehyde. Kalimat, however, is a notable exception. It was tested for two years in the field and in the greenhouse in pots where the soil moisture was controlled. These experiments and the results are described in detail in a separate publication (3). It is sufficient here to present the data on the experiments of 1924 (Table IX, p. 29) and the conclusions from the results of the two years' experiments.

"In all tests during the last two years, kalimat has controlled onion smut just as well as formaldehyde. It is superior to formaldehyde, however, not on account of its fungicidal properties but on account of its comparative safety when used in concentrated solutions or when used in very dry soils. Under these same conditions formaldehyde frequently causes serious injury.

"The claim of the manufacturers that the percentage of germination is increased by the use of kalimat would seem at first to have some support in the data presented. Of the 14 comparisons between treated and check rows, 10 show that there were more seedlings on the treated than on the untreated rows. This does not necessarily mean, however, that kalimat stimulated germination of the seeds; it may have merely killed off some organisms which naturally destroy the seedlings before they reach the surface of the soil.

"The only objection to the use of kalimat is that it is rather expensive at present. It may be obtained for about $1.00 per pint. In larger quantities, however, it could probably be obtained at a lower price. If any considerable demand for it should be developed, the cost of production will be lowered or other substances embodying the same protective principle will appear on the market.

"Of the formulas tried, probably the 1–50–4000 could be recommended as giving excellent control and as being economical of labor and material. This would require about five quarts of kalimat per acre of onions when the rows are thirteen inches apart. In extremely dry soil the same amount applied in greater dilution might have some advantage."

Uspulun. This is a patented German chemical preparation marketed in the form of a purplish gray powder, readily soluble in water to form a purple solution. The active fungicidal principle is orthochlorphenol. In preliminary greenhouse experiments 1 per cent. and 2 per cent. were tried in the formulas 1–50–3000, 1–50–4000, 1–50–5000, 1–100–3000, 1–100–4000 and 1–100–5000. Fair control was secured with all formulas but the best with 1–100–3000. In the field experiments of 1924 the formulas of 1–50–3000 and 1–100–3000 were each used on one row 70 feet long. The percentage of control was just as high as that secured by kalimat or formaldehyde. There was no evidence of seed injury or stunting and the percentage of germination was higher than on the check rows. The results were sufficiently promising to warrant the further testing of this substance. The results will be described more in detail after further tests under different conditions.

Germisan. This is also a German patented disinfectant marketed in the form of a powder but to be used in solution. It has been tried only in our field experiments of 1924 and in the formulas 1–50–3000, 1–50–4000 and 1–50–5000. All formulas gave increased germination and good control of smut. The weakest formula gave just as good control as the others. These results look promising, but we hesitate to make any recommendations until the material has been tried under other conditions.

The other chemical solutions tried gave a percentage of control much lower than formaldehyde.

Dry Chemicals. If some effective and comparatively cheap substance could be found which could be applied as a dry powder it would present certain advantages over solutions: (1) it would eliminate the labor of drawing barrels of water to the field, (2) it would make the drill easier to push because of elimination of the weight of the water, (3) it would eliminate the danger of clogging the seed spout and packing wheel with mud, and (4) machinery for application would probably be simpler and cheaper.

A number of these dry preparations have been tried by the writers but only one up to the present has given a high enough percentage of control to encourage further trials. This is a powder prepared especially for this kind of work by the Corona Chemical Division of the Pittsburgh Plate Glass Company and furnished to the writers under the label "Corona 640." In the preliminary greenhouse tests, this gave better control than any of the others and was, therefore, selected for the field tests of 1924. This was in badly infested soil but at the end of the season the row to which this material was applied contained as many healthy onions as any of the rows treated with the other preparations. There was also an increase in the number of seedlings which came up. Further investigations are now in progress to determine whether the results will be repeated under different conditions and to perfect simple machinery for application.

LITERATURE ON ONION SMUT

1. Anderson, P. J. Development and pathogenesis of the onion smut fungus. Mass. Agr. Expt. Sta. Tech. Bul. 4:99–133. 1921.
2. Anderson, P. J. The relation of soil moisture to formaldehyde injury of onion seedlings. Phytopathology 13:392–403. 1923.
3. Anderson, P. J. Controlling onion smut with Kalimat. Phytopathology 14:569–574. 1924.
4. Anderson, P. J. Comparative susceptibility of varieties of onions and species of Allium to *Urocystis cepulae*. Jour. Agr. Res. (in press). 1925.
5. Anderson, P. J. and A. V. Osmun. An improved formaldehyde tank for the onion drill. Phytopathology 13:161–168. 1923.
6. Barss, H. P. Onion smut control. Oreg. Agr. Expt. Sta. Crop Pest and Hort. Rpt. (1915–20) 3:187–191. 1921.
7. Capron, Horace. Diseases of the onion. U. S. Com. Agr. Rpt. (1869) 8:224. 1870.
8. Clinton, G. P. North American Ustilagineae. Boston Soc. Nat. Hist. Proc. 31:329–529. 1904. (*U. cepulae* on p. 451).
9. Cooke, M. C. Onion smut. Gard. Chron. 7:634. 1877.
10. Cornu, M. Le charbon de l'oignon ordinaire (Allium Cepa), maladie nouvelle, originaire d'Amerique, causee par une Ustilaginee (*Urocystis Cepulae* Farlow). Compt. Rend. Acad. Sci. 89:51–53. 1879.
11. Cornu, M. Maladies nouvelles pour l'Europe, a propos d'une Ustilaginee (*Urocystis Cepulae* Farlow) parasite sur l'oignon ordinaire (Allium Cepa). Bul. Soc. Bot. France 26:263–267. 1879.
12. Cornu, M. Observations sur la maladie des oignons (*Urocystis Cepulae* Farlow). Bul. Soc. Bot. France 27:39–42. 1880.
13. Cotton, A. D. Onion Smut: A disease new to Britain. Jour. Eng. Bd. Agr. 26:168–174. 1919.
14. Farlow, W. G. The onion smut. Abstract of returns of the agricultural societies of Mass. (published with Agr. of Mass. 24 (1876) but paged separately) :164–176. 1877.
15. Farlow, W. G. Notes on some common diseases caused by fungi. Bul. Bussey Inst. 2:114 and 238. 1877.
16. Fernald, H. T. and A. V. Osmun. The control of onion diseases and thrips. Mass. Agr. Col. Ext. Circ. 5. 1916.
17. Frank, A. B. Notiz uber den Zwiebelbrand. Bot. Centbl. 1:186. 1880.
18. Gregory, C. T. The relation of rain to the formaldehyde treatment of onion smut. Phytopathology 12:155–156. 1922.
19. Hallier, E. Der Brandpilz der Kuchenzwiebel, *Urocystis Cepae.* Wiener Illustrirte Garten-Zeitung 5:519. 1880.
20. Halsted, B. D. Fungous disease of various crops. N. J. Agr. Expt. Sta. Rpt. (1890) 11:345–366. 1891.
21. Halsted, B. D. Experiments with onions. N. J. Agr. Expt. Sta. Rpt. (1897) 18:300–302. 1898.
22. Halsted, B. D. Artificial introduction of onion smut. Bul. Torrey Bot. Club 26:74. 1899.
23. Halsted, B. D. Experiments with onions. N. J. Agr. Expt. Sta. Rpt. (1898) 19:319, 320. 1899. See also (1899) 20:392. 1900 and (1896) 17:352. 1897.
24. Jagger, I. C. Diseases of vegetables. West. N. Y. Hort. Soc. Proc. 60:140–147. 1915.
25. Jones, L. R. Onion smut. Vt. Agr. Expt. Sta. Rpt. (1890) 4:141. 1891.
26. Jones, L. R. Investigation of plant diseases. Wis. Agr. Expt. Sta. Bul. 240:47. 1914. See also 250:36. 1915.
27. Liro, J. Ivar. Ueber die Gattung Tuburcinia. Ann. Univ. Fenn. Aboensis Ser. A. T. 1, No. 1:1:153. Turku. 1922.

28. Magnus, P. Bemerkung zu A. B. Frank's Notiz uber den Zwiebelbrand. Bot. Centbl. 1:348. 1880.
29. Malbranche, M. Le Charbon des Oignons. Bul. Soc. Bot. France 28:277–8. 1881.
30. Pammel, L. H. and C. M. King. Four new fungous diseases in Iowa. Iowa Agr. Expt. Sta. Bul. 131:216–220. 1912.
31. Phippin, George D. Report on the onion disease. Proc. Essex Inst. (1857) 2:207, 211–215. 1862.
32. Plant Dis. Bul. Crop losses from plant diseases, 1918. Sup. 6:210. 1919.
33. Proctor, J. W. An essay on the cultivation of the onion. Trans. Essex Agr. Soc. (1847) :86–92. 1848.
34. Schroeter, J. Bemerkungen und Beobachtungen uber einige Ustilagineen. Cohn's Beitr. Biol. Pflanz. 2:349–383. 1877. (Polycystis Colchici on p. 378–9).
35. Selby, A. D. Onion smut. Ohio Agr. Expt. Sta. Bul. 122:71–84. 1900.
36. Selby, A. D. The prevention of onion smut. Ohio Agr. Expt. Sta. Bul. 131:47–51. 1902.
37. Sirrine, F. A. and F. C. Stewart. Experiments on the sulphur-lime treatment for onion smut. N. Y. (Geneva) Agr. Expt. Sta. Bul. 182:145–172. 1900.
38. Sorauer, P. *Urocystis Cepulae.* Handbuch d. Pflanzenkrankheiten 2:333. 1908.
39. Stone, G. E. The control of onion smut. Mass. Agr. Expt. Sta. Circ. 52. 1915. Also Mass. Agr. Expt. Sta. Rpt. (1908) 21, Pt. 1:48, 49. 1909.
40. Sturgis, W. C. Common fungous diseases and their treatment. Conn. State Agr. Expt. Sta. Bul. 111:14. 1892.
41. Sturgis, W. C. Diseases of the onion. Conn. State Agr. Expt. Sta. Bul. 115:14, 15. 1893.
42. Sturgis, W. C. Transplanting as a preventive of smut upon onions. Conn. State Agr. Expt. Sta. Rpt. (1895) 19:176–182. 1896.
43. Taylor, Thomas. Onion blight and smut. U. S. Com. Agr. Rpt. (1872) :193–195. 1874.
44. Thaxter, R. The smut of onions (*Urocystis cepulae* Frost). Conn. State Agr. Expt. Sta. Rpt. (1889) 13:129–153. 1890.
45. Thaxter, R. Further experiments on the smut of onions. Conn. State Agr. Expt. Sta. Rpt. (1890) 14:103–104. 1891.
46. Vaughan, R. E. and J. C. Walker. Onion smut. Wis. Hort. 10:133–145. 1920.
47. Walker, J. C. Onion diseases and their control. U. S. D. A. Farmers' Bul. 1060:1–23. 1919.
48. Walker, J. C. Experiments upon formaldehyde drip control of onion smut. Phytopathology 10:323–327. 1920.
49. Walker, J. C. Observations on the cultivation and diseases of cabbage and onions in Europe, 1922. Plant Dis. Reporter Sup. 32:1–33. 1924.
50. Walker, J. C. and L. R. Jones. Relation of soil temperature and other factors to onion smut infection. Jour. Agr. Res. 22:235–261. 1921.
51. Ware, Benj. P. Experience of a practical farmer. Abstract of returns of the agricultural societies of Mass. (published with Agr. of Mass. 17 (1869) but paged separately) :10. 1870.
52. Whitehead, T. Experiments on the control of onion smut. Jour. Min. Agr. Eng. 28:443–450. 1921.
53. Whitehead, T. On the life history and morphology of *Urocystis cepulae.* Trans. Brit. Myc. Soc. 7, Pt. 2. 1921.
54. Zillig, H. Ustilagineen in Sorauer's Handbuch d. Pflanzenkrankheiten 4:298–299. 1923.
55. Zillig, H. Unsere heutigen Kenntnisse vom Zwiebelbrand (*Tuburcinia cepulae* (Frost) Liro). Centbl. Bakt. (Abt. 2) 60:50–58. 1923.

APPENDIX

TABLE I.

Cowls Farm Experiment, 1919

Treatment Formula	100 Ft. of Row on June 2			100 Ft. Harvested September 15				Gain in Pounds per Acre
	Standing Onions	Per Cent. Smut	Total Gain in Healthy Plants	Number Onions Harvested	Gain in Bulbs	Weight in Pounds	Gain in Lbs.	
1- 64-3200	2120	11.3	1222	773	596	105	66	26,400
1- 96-3200	2256	12.8	1308	844	667	116	77	30,800
1-128-3200	1923	17.7	825	936	759	112	73	29,200
Untreated	1325	50.4		177		39		

TABLE II.

C. A. Clark Experiment, 1920

Treatment Formula	Feet of Row Treated	Average Harvest for 100 Ft.				Gain in Pounds per Acre
		No. of Bulbs Harvested	Gain Over Check	Weight of Bulbs Harvested (Pounds)	Gain in Pounds Over Check	
1-128-3000	1068	736	301	120	42	18,295
1- 96-3000	1068	769	334	121	43	18,731
1- 64-3000	1068	782	347	122	44	19,166
1- 48-3000	1068	686	251	117	39	16,988
1- 32-3000	534	758	323	125	47	20,473
1- 50-4000	534	694	259	114	36	15,682
1- 50-5000	534	615	180	108	30	13,068
Untreated	2136	435		78		

TABLE III.

Kuzmeski Farm Experiment, 1920

Treatment Formula	Feet of Row Treated	Average Harvest for 100 Ft.		Percentage of Increase
		Number of Bulbs Harvested	Gain in Bulbs Over Check	
1-96-3000	3488	849	493	137
1-50-5000	3488	610	254	72
Untreated	1744	356		

TABLE IV.

C. A. Clark Experiment, 1922

Treatment Formula	Percentage Methyl Alcohol	Feet of Row Treated	Average of 100 Feet		Percentage of Increase
			No. Bulbs Harvested	Gain in Bulbs Over Check	
1- 50-3000	6-14	2000	230	54	30
1- 50-3000	.4	1000	288	112	64
1- 50-3000	16.	1000	234	58	33
1- 50-4000	6-14	2000	238	62	35
1- 50-5000	6-14	2000	285	109	62
1- 64-3000	6-14	1000	268	92	53
1-128-3000	6-14	1000	303	127	72
Untreated		3000	176		

TABLE V.

Kuzmeski Farm Experiment, 1922

Treatment Formula	Feet of Row Treated	Average Harvest for 100 Feet		Percentage of Gain
		No. of Sound Bulbs	Gain in Bulbs Over Check	
1-50-3000	880	580	203	53
1-50-4000	880	576	199	53
1-50-5000	880	699	322	85
Untreated	880	377		

TABLE VI.

Allen Clark Farm Experiment, 1923

Treatment Formula	Feet of Row Treated	Average Harvest for 100 Feet		Percentage of Gain
		No. of Sound Bulbs	Gain Over Check	
1- 64-3000	1132	737	611	485
1- 75-3000	1132	733	607	482
1- 50-3000	1132	565	439	350
1-100-3000	1132	677	551	437
1- 50-4000	1132	721	595	472
1- 50-5000	566	339	213	169
Untreated	1698	126		

TABLE VII.

Kuzmeski Farm Experiment, 1923

Treatment Formula	Feet of Row Treated	Per Cent. Chemical Loss	Average Harvest on 100 Feet		
			No. of Sound Bulbs	Gain Over Check	Per Cent. Shrinkage June 1 to Sept. 3
1- 50-3000	1744	57	299	- 8	29
1- 50-4000	1744	51	262	-45	33
1- 50-5000	1744	20	338	31	38
1- 64-3000	872	41	285	-22	40
1- 75-3000	872	32	356	49	35
1-100-3000	872	36	314	7	36
Untreated	2616		307		62

TABLE VIII.

College Farm Experiment, 1923

Treatment Formula	Feet of Row Treated	Per Cent. Chemical Loss	Per Cent. Shrinkage June 1—Aug. 30	Final Gain Over Check per 100 Feet
1- 50-3000	300	70	25	-31
1- 50-4000	300	49	39	23
1- 50-5000	300	30	33	95
1- 64-3000	300	72	28	63
1- 75-3000	150	60	31	7
1-100-3000	300	48	40	22
Untreated	975		73	

TABLE IX.

Comparison of Kalimat and Formaldehyde in the Field Tests of 1924 Each Row 70 Feet Long

Chemical	Formula	Number of Rows Treated	Average Number of Seedlings Which Came up per Row	Average Sound Onions Harvested per Row
Check		12	539	122
Kalimat	1- 50-5000	8	544	340
Formaldehyde	1- 50-5000	8	538	309
Kalimat	1- 50-4000	8	625	432
Formaldehyde	1- 50-4000	8	525	331
Kalimat	1- 50-3000	4	516	380
Formaldehyde	1- 50-3000	4	469	285
Kalimat	1-100-3000	4	593	331
Formaldehyde	1-100-3000	4	416	293

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 222 March, 1925

EXPERIMENTS ON THE CONTROL OF APPLE SCAB AND BLACK ROT AND SPRAY INJURY IN 1924

By W. L. Doran

This bulletin reports the results obtained, during the past season, in the study of the control of apple scab and black-rot. Incident to the main problems there have been comparisons of spraying and dusting, and observations on many related subjects. The difficulty which led to such widespread injury from apple scab, previous to the initiation of this work in 1921, was in the spray calendar, particularly with reference to the prepink and pink sprays or dusts. Greater care in these applications seems to be absolutely essential in any thoroughgoing attempt to control this destructive disease.

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AGRICULTURAL EXPERIMENT STATION
AMHERST, MASS.

EXPERIMENTS ON THE CONTROL OF APPLE SCAB AND BLACK ROT AND SPRAY INJURY IN 1924.*

By W. L. Doran

The experiments of 1924† were planned with the object of securing further data on the comparative efficiency of several materials and schedules in controlling apple scab caused by *Venturia inaequalis*. In addition to this, some attention was given to black-rot caused by *Physalospora cydoniae*, with a view to increasing our knowledge of its economic importance, seasonal occurrence, and control in Massachusetts. Data were also secured which, it is believed, will assist orchardists in reducing the severity of spray injury on fruit and foliage.

Materials and Methods.

At Middlesex Fruit Farm, Gravensteins having a spread of about 35 feet and a height of about 25 feet were sprayed, and Baldwins having a spread of about 30 feet and a height of about 25 feet were dusted. At both Harvard Fruit Farm and Pine Crest Orchard only McIntosh trees were used. At the former orchard these trees are eight years old and about 15 feet in height and diameter, and at the latter orchard they are 11 years old and larger in proportion.

At Harvard Fruit Farm and Pine Crest Orchard, Friend sprayers were used with a pressure of about 200 pounds. At Middlesex Fruit Farm an Arlington X L Sprayer was used with a pressure of about 150 pounds. At Middlesex Fruit Farm two spray rods were used. Spray guns were used at Pine Crest Orchard and at Harvard Fruit Farm, two at the former and one at the latter.

At Middlesex Fruit Farm liquid lime-sulfur, 1 gallon in 50 gallons, was used; and in the other orchards dry lime-sulfur, 4 pounds in 50 gallons, was used.

Lead arsenate was present in all sprays or dusts in the usual proportions for the pink and calyx applications and for the application about two weeks after the calyx.

The Bordeaux mixture used was of the 3-10-50 formula.

Dry-mix sulfur-lime was made up to contain 8 pounds of sulfur, 4 pounds of hydrated lime, and ½ pound of calcium caseinate in 50 gallons of spray, as described by Farley.**

The copper dust used contained 11 per cent monohydrate copper sulfate. The sulfur dust used contained 90 parts or 85 parts sulfur, and 10 parts or 15 parts lead arsenate in 100 parts. Niagara Sulfo-dust without arsenic was used for all applications except those specified above as receiving an arsenical.

The dusting was done with Niagara power dusters. In dusting, the halves of the application were not "split," that is, at each application each tree was dusted from two sides. The dusting was done either early in the morning or in the evening, in order to have the foliage moist and to avoid wind.

Two McIntosh orchards were dusted and two McIntosh orchards were sprayed. An orchard of Gravensteins was sprayed and an orchard of Baldwins was dusted.

All plots were sprayed or dusted at least four times. The dates of applications were as follows in the McIntosh orchards: prepink, May 5-7; pink, May 14-17; calyx, May 31—June 2; fourth, June 11-16; fifth spray, July 14; fifth dust, June 30—July 1; sixth dust, July 14-15; seventh dust, August 9-11. On the other varieties, the applications were made at about the same time, although in the case of the preblossom and calyx applications, the Gravenstein orchard received treatment a few days before the McIntosh, and the Baldwins a few days after the McIntosh.

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* *Acknowledgment*. This work was done with the co-operation of the Nashoba Fruit Producers' Association, in the following orchards: Mr. Albert Jenks' Middlesex Fruit Farm, West Acton; Mr. Stephen W. Sabine's Pine Crest Orchard, Groton; and Mr. Philip H. Babcock's Harvard Fruit Farm, Harvard. In scoring the fruit, assistance was given by Professors A. I. Bourne, B. D. Drain, J. S. Bailey, and W. H. Thies of Massachusetts Agricultural College. Mr. W. P. Wharton furnished rainfall records.

† For results of earlier experiments in Massachusetts, see: Mass. Agr. Expt. Sta. Bulletins 214 and 219.

** Farley, Arthur J. Dry-mix sulfur lime. New Jersey Agr. Expt. Sta. Bul. 379. 1923.

Relation of the Weather to Infection and to Disease Severity.

There was rain on nineteen days in May, and ascospores were ejected on each of these days. The combination of rain, viable ascospores, and susceptible host tissue resulted in a condition most favorable to scab infection. In 1924, ascospores were mature and beginning to be discharged earlier with reference to the condition of apple bud development than in 1923. In Baldwin orchards where no spray was applied before the pink application considerable primary infection was permitted.

The precipitations for June and July were below the normals for these months. Rain fell on eleven days in June and on seven days in July. As a result of the dry summer, scab control was not difficult, and the year was characterized by scab infestation of average rather than exceptional severity. This would seem to indicate that rainy weather before and during the period of flowering may not have any greater influence on the percentage of scabby apples at picking time than has the rainfall of the summer.

Not more than 7.0 per cent of the fruit on any check plot developed black-rot. The rarity of black-rot and frog-eye leaf spot was presumably the result of the relative dryness of the weather in June and July, for the rainfall was abundant in May and was not below normal in August.

Scab Infection on Leaves.

On June 9, after the trees had received prepink, pink and calyx applications, accessible leaves were scored for scab lesions. This was only ten days after the first scab infection of the season was found, and the count therefore gives us a very fair indication of the relative success of the several treatments in preventing the primary infection. The results are given in Table I.

In all orchards there was somewhat less scab on trees dusted with copper-lime-arsenic dusts at the prepink and pink applications than on trees dusted with sulfur. This difference, it should be added, practically disappeared later in the season.

There was at this time less scab infection on the leaves of sprayed trees than on the leaves of dusted trees, due probably to the more rapid removal of the dust by the frequent rains in May.

Lime-sulfur solution (with or without spreader), Bordeaux mixture and dry-mix sulfur-lime were practically equally successful in preventing the primary infection.

Set of Fruit as Affected by Scab and by Fungicides.

Scab infection on pedicels resulted in the early fall of many flowers and young fruits on check trees at the Harvard Fruit Farm. Flowers were counted on marked limbs in each plot at this orchard, and on June 30 the fruits which had set on these limbs were counted. In sprayed or dusted plots from 3.0 to 5.0 per cent of the flowers had set fruit and on check trees from 0.9 to 1.5 per cent of the flowers had set fruit. The fungicides, by preventing pedicel infection, increased the set of the fruit.

Control of Scab on the Fruit.

These results are given in Table II. In considering scab control, it is first of all necessary to take into account the degree of scabbiness of fruit on check trees. The percentages of scabby fruits on check trees in the several orchards were as follows:

Pine Crest Orchard	(check for sprayed plots)	69.4
Pine Crest Orchard	(check for dusted plots)	45.8
Harvard Fruit Farm	(check for sprayed plots)	81.0
Harvard Fruit Farm	(check for dusted plots)	84.2
Middlesex Fruit Farm	(check for dusted plots)	50.2

Results in the sprayed plots.—Four applications of lime-sulfur solution without spreader may be regarded as the standard treatment. With this treatment at Pine Crest Orchard there was 1.2 per cent scabby fruit, and at Harvard Fruit Farm, 0.2 per cent scabby fruit. This adds to the evidence, already abundant, that lime-sulfur is a dependable fungicide against apple scab.

The protection afforded by lime-sulfur without the calcium caseinate spreader is so nearly complete that it is not surprising to find the use of the spreader without benefit in scab control. In fact, at both Harvard Fruit Farm and Pine Crest Orchard there was slightly less scab where no spreader was used than on plots where it was used. It is certain that the addition of the spreader to lime-sulfur-lead arsenate does not increase the efficiency of the fungicide in preventing apple scab.

A fifth application of lime-sulfur solution was applied to certain plots the middle of July because black-rot as well as scab was under observation, although neither the weather conditions nor the prevalence of scab indicated any necessity for it. This application followed six weeks of dry weather, and there was less than 2.0 per cent scabby fruit on the trees. The fifth application did not prove necessary since the protection given by four applications, as revealed at picking time, could hardly be excelled. In August, 1924, there was rain on a greater number of days than is normal for the month, and we may conclude that the necessity for a late application for scab control is affected less by the rainfall of August than by the degree of scabbiness attained by the tree in June and July.

Dry-mix sulfur-lime did not control scab as thoroughly as did lime-sulfur. In one orchard, in the plot sprayed with dry-mix sulfur-lime 8.8 per cent of the apples were scabby, and in the plot sprayed with lime-sulfur there were 0.2 per cent scabby apples. In another orchard there was 3.5 per cent scabby fruit in the dry-mix sulfur-lime plot, and 0.2 per cent scabby fruit in the lime-sulfur plot. Evidently on varieties as susceptible to scab as McIntosh, dry-mix sulfur-lime is not equal to lime-sulfur in protecting against scab.

The substitution of Bordeaux mixture for lime-sulfur for the prepink and pink applications gave practically perfect protection against scab, but the use of lime-sulfur for all applications gave protection essentially as good. Since, as is brought out elsewhere in this report, Bordeaux mixture costs somewhat more than lime-sulfur, and since Bordeaux mixture, even when used only for the prepink and pink applications, is more likely to cause fruit russeting than is lime-sulfur, the use of Bordeaux mixture at all seems to be a practice of rather doubtful value.

Results in the dusted plots.—In both McIntosh orchards the percentage of scabby apples was slightly less in the plots on which copper dust was substituted for sulfur dust for the first two applications, than in the plots dusted with sulfur at all applications. But this difference was too small to be important.

In each orchard there were four plots dusted with sulfur four, five, six and seven times respectively. The increase in the number of applications beyond four or five did not result in any consistent increase in protection against scab. The average percentage of scabby apples on plots dusted with sulfur four, five, six or seven times was as follows: Baldwins 6.9, McIntosh (Pine Crest Orchard) 3.2, McIntosh (Harvard Fruit Farm) 3.8. When the fifth application was made, about June 30, 10.0 to 15.0 per cent of the leaves were scabby. The infrequency of rains thereafter made later applications unnecessary.

INJURY TO LEAF AND FRUIT BY SPRAYS AND DUSTS.

Leaf Injury.—Leaf injury was more pronounced on McIntosh than on Gravenstein or Baldwin. Leaves on check trees, which of course received no spray or dust except arsenate, were all large, flat, and uniformly green with no pale margins. Leaves on trees dusted with sulfur had practically the same appearance as leaves on check trees, that is, they were entirely uninjured and showed no tendency to curl or for the leaf margin to become pale. Leaves on trees sprayed with lime-sulphur-lead arsenate were somewhat curled, spoonshaped, or cupped. Many had pale yellowish-green margins, with some marginal burning.

The addition of calcium caseinate spreader to lime-sulfur-lead arsenate spray did not reduce the injury to the leaves.

The foliage of trees sprayed with dry-mix sulfur-lime was not injured as much as that on trees sprayed with lime-sulfur. In fact, there was practically no visible injury on leaves sprayed with dry-mix sulfur-lime.

A fifth application of lime-sulfur resulted in no more leaf injury than was present on plots sprayed four times. Injury occurred when the calyx and fourth summer sprays were applied. When these applications were made, the spray dried on the foliage in about twenty minutes and the temperature was between 55° and 67° F. These conditions are not such as are popularly regarded as conducive to spray injury. Nevertheless, spray injury as above described did occur when lime-sulfur-lead arsenate spray was applied.

Another type of spray injury, also practically confined to trees sprayed with lime-sulfur, consisted in the killing of leaf tissue under and around scab lesions.

Spray injury to the fruit as revealed at picking time.—Fruit russeting was much more severe on Gravenstein than on McIntosh or Baldwin. (See Table III.)

The addition of calcium caseinate spreader to lime-sulfur-lead arsenate spray resulted, in the case of Gravenstein, in a reduction of about 50 per cent in the amount of russet. When this spray was used without spreader, 16.0 per cent of the apples were russeted; when used with spreader, 8.4 per cent of the apples were russeted. The addition of the spreader was evidently of very considerable benefit but by no means did it prevent all russeting; for there was nearly four times as much injury, even where the spreader was used, as there was on the check plot. On McIntosh plots sprayed with lime-sulfur there was so little russeting, either with or without the spreader, that no benefit from the use of the spreader was evident.

The substitution of Bordeaux mixture for lime-sulfur for the prepink and pink applications resulted in more russeted fruit than when lime-sulfur was used for all applications. In the Gravenstein orchard there was 13.1 per cent russeted fruit where Bordeaux mixture was used and 8.4 per cent on the plot on which lime-sulfur was used for all four applications. Similarly, in the two McIntosh orchards there were 14.7 and 13.5 per cent russeted apples on plots receiving the preblossom applications of Bordeaux mixture, and 0.2 and 0.4 per cent russeted apples, respectively, on plots where lime-sulfur was used for all applications.

With the substitution of copper dust for sulfur dust for the preblossom applications in the two McIntosh orchards, there were 11.1 per cent and 5.0 per cent russeted fruit. The percentages of russeted fruit in these two orchards in plots dusted with sulfur for all applications were 0.8 per cent and 0.6 per cent respectively. In the Baldwin orchard the difference was not as great: there was 2.2 per cent russet where sulfur dust was used, and 4.0 per cent russet where copper dust was substituted for the prepink and pink applications But on McIntosh, especially, there is evidence that even for preblossom applications copper dust is more likely to result in russeted fruit than is sulfur dust.

There was practically the same percentage of russeted fruits on plots sprayed four times with lime-sulfur as on plots which received a fifth application of lime-sulfur (about the middle of July).

Apparently, late applications of sulfur dust are as safe as the earlier ones, for there were no consistent or significant differences in the amount of russeting of fruit on plots dusted four, five, six or seven times.

BLACK-ROT AND FROG-EYE LEAF-SPOT.

In April and May large numbers of the pycnospores of the causal fungus were found on the surface of the bark of cankered limbs. Such limbs were sprayed in the laboratory with Bordeaux mixture or with lime-sulfur, and spores so treated would not germinate although 95 to 100 per cent of spores from limbs not sprayed germinated. This means that the preblossom applications must have disinfecting values, in that they kill such of the spores of this fungus as are at that time exposed on the surface of the bark of cankered twigs and limbs.

The first frog-eye leaf-spot was observed June 9. There was a slight increase in the number of these leaf-spots up to July 25, but there was no increase after that, at least on the marked branches used for earlier counts. On July 21, in the Baldwin orchard, 9.0 per cent of the accessible leaves on check trees, and an average of 3.0 per cent of the accessible leaves on all dusted plots had frog-eye leaf-spot.

In neither of the McIntosh orchards or in the Gravenstein orchard was there more than 0.5 per cent black-rot on fruits in check plots at picking time. Only in the Baldwin orchard was there enough black-rot to enable us to secure any information as to relative efficiency of the several treatments in controlling this disease. In this orchard 7.2 per cent of the fruit on check trees, 2.0 per cent of the fruit on the plot dusted with copper dust followed by sulfur dust, and an average of 0.9 per cent of the fruit on all plots dusted with sulfur dust showed black-rot infection. The infection on the check was of course light, but we have some indication of the protection against black-rot given by the dust treatment.

Cost of Dusting and Spraying.

This includes the cost of materials and the cost of labor, but not the cost of equipment. The cost of treatment for one tree for the season is given in Table IV.

The labor involved was performed by two men and two horses at each orchard, except Middlesex Fruit Farm where but one horse was used. Further details as to size of trees and labor are given under the section on "Methods and Materials."

On the Gravensteins of the Middlesex Fruit Farm, 690 gallons of liquid and seven hours of labor were required to spray 100 trees. To dust 100 Baldwins here required 50 minutes and 127 pounds of sulfur dust. At Harvard Fruit Farm, 100 trees were sprayed in two hours, using 160 gallons of liquid. One hundred trees of this size were dusted in 33 minutes, using 75 pounds of sulfur dust. At Pine Crest Orchard, 100 trees were sprayed in two and three-fourths hours, using 360 gallons of liquid. One hundred trees at this orchard were dusted in 35 minutes, using 110 pounds of sulfur dust.

Although liquid lime-sulfur was not used at Harvard Fruit Farm or Pine Crest Orchard, it is also included in the record of costs for purposes of comparison.

A study of Table IV makes it evident that our cheapest method of protection is to spray with liquid lime-sulfur. Dry-mix sulfur-lime is more expensive, although the difference is not so great if dry rather than liquid lime-sulfur is considered. Bordeaux mixture is intermediate in cost between dry and liquid lime-sulfur. Use of the spreader necessarily increases the cost.

As to whether spraying or dusting is cheaper depends on the facilities for spraying, the distance from the water supply, the size of the spray tank, the size of the trees, and how many applications of dust are considered necessary. Five applications of dust were enough in 1924. This being the case, it was as cheap to protect by dusting as by spraying at Middlesex Fruit Farm. At the other two orchards, with smaller trees and less time spent in going for water, protection proved somewhat cheaper by spraying than by dusting, provided that our cheapest spray material is considered.

In most orchards where dry lime-sulfur and spreader is to be used, it is probable that the cost will not be far from that of dusting.

Summary.

The primary infection of the leaves was prevented equally well by lime-sulfur, Bordeaux mixture, and dry-mix sulfur-lime. The primary infection of the leaves was prevented more completely by spraying with lime-sulfur than by dusting with sulfur.

The prevention of pedicel infection by the fungicides improved the set of fruit.

On McIntosh plots sprayed with lime-sulfur four times, there were 1.2 per cent and 0.2 per cent scabby apples; while on their respective check plots there were 69.4 per cent and 81.0 per cent scabby apples.

The addition of calcium caseinate spreader to lime-sulfur-lead arsenate spray did not result in increased protection against scab.

A fifth application of lime-sulfur did not increase the protection against scab afforded by four applications. The necessity for a late application for scab control is probably affected less by the rainfall of August than by the degree of scabbiness attained by the tree in June and July.

Dry-mix sulfur-lime did not control scab on McIntosh as completely as did lime-sulfur.

The substitution of Bordeaux mixture for lime-sulfur for the preblossom applications gave practically perfect protection against scab, but the use of lime-sulfur for all applications gave protection which was essentially as good.

Sulfur dust gave satisfactory control of scab. In McIntosh orchards there was an average of 3.5 per cent scabby apples on plots dusted with sulfur, while on the check plots there was an average of 65.0 per cent scabby apples. No proof was secured that it is necessary to substitute copper dust for sulfur dust for the preblossom applications.

Lime-sulfur-lead arsenate spray caused foliage injury, and this was not prevented by the addition of calcium caseinate spreader. Leaves on trees dusted with sulfur or sprayed with dry-mix sulfur-lime were not visibly injured.

The addition of calcium caseinate spreader to lime-sulfur-lead arsenate spray resulted in a reduction of about 50 per cent in the amount of russeted fruits on Gravensteins.

There was a larger percentage of russeted apples on plots on which Bordeaux mixture or copper dust was used for preblossom applications than on plots sprayed with lime-sulfur or dusted with sulfur at all applications.

In the Baldwin orchard, there were three times as many leaves with frog-eye leaf-spot on check trees as on trees dusted with sulfur. In this orchard, 7.2 per cent of the fruit on check trees became infected with black-rot and the disease was present on 0.9 per cent of the fruit dusted with sulfur.

The costs of various treatments are recorded and compared. The costs of spraying and of dusting are not very far apart.

TABLE 1.—SCAB ON LEAVES

Variety*	† Treatment	Per cent Scab
Baldwins	Check	24
	Copper dust, prepink and pink; sulfur dust at calyx application	7
	Sulfur dust	11
McIntosh	Check	27
	Copper dust, prepink and pink; sulfur dust at calyx application	8
	Sulfur dust	14
McIntosh	Check	45
	Sprayed with Bordeaux, prepink and pink; calyx application of lime-sulfur	1
	Sprayed with lime-sulfur-lead arsenate, without spreader	1
	Sprayed with lime sulfur-lead arsenate with spreader	1
	Sprayed with dry-mix sulfur-lime	2
McIntosh	Check	30
	Copper dust, prepink and pink; sulfur dust at calyx application	4
	Sulfur dust	7
McIntosh	Check	34
	Sprayed with Bordeaux, prepink and pink; calyx application of lime-sulfur	1
	Sprayed with lime-sulfur-lead arsenate, without spreader	1
	Sprayed with lime sulfur-lead arsenate with spreader	1
	Sprayed with dry-mix sulfur-lime	3

* Separate orchards indicated by brackets.

† Up to June 9, through calyx application.

Table II.—Scab Control.

(Fruit counts in August, September and October, at picking time.)

Treatment	Number of Applications	Per cent Scabby Fruit		
		Baldwins	McIntosh	
		Middlesex Fruit Farm	Pine Crest Orchard	Harvard Fruit Farm
Check for sprayed orchards	None		69.4	81.0
Lime-sulfur without spreader	Four		1.2	0.2
Lime-sulfur with spreader	Four		2.4	
Lime-sulfur without spreader	Five		0.2	0.0
Lime-sulfur with spreader	Five			2.4
Dry-mix sulfur-lime	Four			3.5
Dry-mix sulfur-lime	Five		8.8	
Bordeaux, prepink and pink; followed by lime-sulfur	Four			0.0
Bordeaux, prepink and pink; followed by lime-sulfur	Five		0.1	
Check for dusted orchards	None	50.2	45.8	84.2
Sulfur dust	Four	9.2	1.5	5.4
Sulfur dust	Five	4.7	2.3	3.3
Sulfur dust	Six	8.5	3.1	3.8
Sulfur dust	Seven	5.3	6.0	2.8
Sulfur dust (average of plots)	Four to Seven	6.9	3.2	3.8
Copper dust, prepink and pink; followed by sulfur dust	Five	7.3	1.2	2.4

TABLE III.—SPRAY INJURY.

Russeting of Fruit.

Treatment	Number of Applications	Per cent of Fruit Russeted			
		Middlesex Fruit Farm		Pine Crest Orchard McIntosh	Harvard Fruit Farm McIntosh
		Gravenstein	Baldwin		
Check for sprayed orchards	None	2.7		0	0
Lime-sulfur-lead arsenate spray:					
Without spreader	Four	16.0		0.8	0.4
With spreader	Four	8.4		0.9	
Without spreader	Five			0.6	0.8
With spreader	Five	9.0			0.9
Dry-mix sulfur-lime-lead arsenate spray	Four				0.9
Dry-mix sulfur-lime-lead arsenate spray	Five	4.6		0.3	
Bordeaux mixture, prepink and pink; followed by lime-sulfur-lead arsenate spray:					
With spreader	Four	13.1			13.5
Without spreader	Five			14.7	
Check for dusted orchards	None		0.4	0.5	0
Sulfur dust	Four		2.3	1.6	0
Sulfur dust	Five		2.2	0.9	0.8
Sulfur dust	Six		1.3	0.5	1.0
Sulfur dust	Seven		4.8	0.3	0.6
Sulfur dust (average of plots)	Four to Seven		2.2	0.8	0.6
Copper-lime-arsenic dust, prepink and pink; followed by sulfur dust	Five		4.0	11.1	5.0

TABLE IV.—COST PER TREE.

Treatment	Number of Applications	Middlesex Fruit Farm	Pine Crest Orchard	Harvard Fruit Farm
Lime-sulfur without spreader	Four		$.33* .26†	$.19* .16†
Lime-sulfur with spreader	Four	$.56†	.35* .29†	
Lime-sulfur without spreader	Five	.60†	.39* .31†	.19†
Lime-sulfur with spreader	Five	.67†		.20†
Dry-mix sulfur-lime	Four		.38	.20
Dry-mix sulfur-lime	Five	.81		
Bordeaux mixture, prepink and pink; followed by lime-sulfur with spreader	Four	.63†		
Bordeaux mixture, prepink and pink; followed by lime-sulfur without spreader	Four		.31†	.17†
Sulfur dust	Four	.48	.30	.25
Sulfur dust	Five	.56	.35	.29
Sulfur dust	Six	.64	.39	.33
Sulfur dust	Seven	.72	.44	.37
Copper dust, prepink and pink; followed by sulfur dust	Four	.50	.36	.33
Copper dust, prepink and pink; followed by sulfur dust	Five			

* Dry lime-sulfur. † Liquid lime-sulfur.

V

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 223 March, 1925

MILK SUBSTITUTES IN THE REARING OF YOUNG CALVES

By J. B. Lindsey and J. G. Archibald

Dairy farms located adjacent to their market, as are most of those in Massachusetts, usually find it more profitable to sell fluid milk than to sell cream and use the skim milk in growing young stock. The relatively high price of fluid milk has been an incentive to better the grade of stock kept on our dairy farms, while the same cause has made it unprofitable to rear calves from this high grade stock. Unless a substitute for milk, to be used in rearing calves, can be found, one of the great advantages of high grade producing stock on our dairy farms cannot be realized. It was to meet this need that the work here reported was initiated. The bulletin presents the report of seven different feeding trials with forty-five different animals.

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AGRICULTURAL EXPERIMENT STATION
AMHERST, MASS.

MILK SUBSTITUTES IN THE REARING OF YOUNG CALVES.

by

J. B. LINDSEY AND J. G. ARCHIBALD.

Introduction.

The problem of rearing calves for the first four to six months of their lives without the liberal use of whole or skim milk has been studied by many agricultural investigators. Where plenty of whole and skim milk are available it is a relatively simple matter, provided one understands the technique of calf rearing, which includes cleanliness in care and feeding and close observation to prevent overfeeding. Much depends on the calf itself; some are thrifty and require but little attention, while others are delicate and finicky, and require constant attention and considerable skill to bring them through their babyhood.

In the three southern New England states most of the product of the dairy herd is sold as whole milk, hence very little of either whole or skim milk is available for feeding purposes. In northern New England, where creameries are still in operation and skim milk and pasture are available, large numbers of dairy cows should be raised to supply the needs of the dairymen farther south. Even were this practice followed to a greater extent than it is at present, dairymen could still be found throughout southern New England desirous of raising more or less of their own stock. They have been and are still confronted with the difficulty of finding a suitable substitute for the relatively expensive milk.

It is not the intention in this publication to review in detail the work of the many investigators who have studied the problem, but rather to state briefly the different types of substitutes that have been fed and the results secured, and in addition to give a brief summary of our own more recent study of the subject.

In most of the older investigations reported, skim milk was used extensively, supplemented with numerous substances such as cod liver oil, coconut oil, flaxseed jelly, starch, rolled oats, etc. Some form of oats, either crushed, rolled, whole, or oat meal, seems to have been the most universal supplement and to have given the best results. The problem, however, with skim milk unavailable is to find some substitute that will take its place and produce thrifty calves.

The substitutes used in more recent studies can be grouped under four general heads:

1. Calf meals compounded from cereal grains, oil seeds and oil cakes, and leguminous seeds.
2. Meals similar to those in (1) supplemented with such animal proteins as blood flour and skim-milk powder.
3. Manufactured milk by-products, such as skim-milk powder, malted milk residue, semi-solid buttermilk and buttermilk powder.
4. Infusions of clover hay, of flaxseed, and of such meals as bean meal and linseed oil meal.

The feeding trials with these various mixtures have been carried on at widely separated points, under varying conditions and in many cases with an insufficient number of animals; so that it is not possible to state positively which type of substitute has given the most satisfactory results. The success of the different types as measured by daily gain in weight of the calves has varied from fair to excellent, largely due, no doubt, in most instances, to differences in the vigor of the individual calves. In general fair growth has been produced, the average being about a pound to a pound and a quarter daily. The few trials that have been made with the materials in Group 3 indicate that they are more suitable for calves up to six or eight weeks of age than are meals made from grains. Considering their source this is what would naturally be expected. In Groups 1 and 2 linseed meal and some form of oats seem to have been universally used. Obviously no statement as to comparative costs can be made. That depends on current prices and materials locally available.

Recent Experiments at this Station.

Our own more recent investigation of the problem commenced in the fall of 1921, and is still in progress. This article reports results up to June, 1924, at which time seven different substitutes had been given a trial and forty-five calves had been more or less successfully raised.

In formulating our substitutes the following essentials have been taken into consideration:

1. Variety and completeness of protein.
2. Sufficient carbohydrate to balance the ration satisfactorily.
3. Plenty of vitamines.
4. Sufficient mineral matter.

Method of Feeding.

Our method of feeding has been planned so as to have the calves weaned from whole and skim milk as early as possible. The calves are left with their dams only twenty-four hours, at the end of which time they are taught to drink whole milk from a pail. The milk fed to them is always from one of the lowest testing Holstein cows in the herd, and the maximum fed is six quarts daily. When the calf is a week to ten days old the whole milk is gradually replaced by skim milk. If it is a vigorous animal it will be receiving skim milk entirely by the end of the second week. When the calf is from two to three weeks old the skim milk is gradually replaced, a quart at a time, by a gruel made from the meal which it is desired to give a trial. The gruel is made by mixing the meal with water in the proportion of 3½ ounces of meal to each quart of water. It is stirred up with a little cold water first so lumps will not form, and then the correct amount of warm water is added, and the gruel fed at blood heat, never cold or very hot. Skim milk, while it continues to be fed, is mixed with the gruel at feeding time. By the time the calf is a month old it is receiving only two or three quarts of skim milk daily and this is gradually withdrawn so that before it is two months old it is weaned from milk entirely. Ten quarts of liquid is the average maximum fed.

This schedule cannot be blindly adhered to, because calves differ greatly in their individual appetites and ability to stand the changes in feed, but it serves as a general guide. The calves have been taught to eat rowen and dry grain as early as possible. Most of them have learned to eat these feeds at about four to five weeks of age.

The feeding trials have in every instance been discontinued at four months of age as it is considered that by that time the critical period of the calf's existence has been passed. All calves have been weighed weekly and their progress carefully noted.

The calf meals have been mixed as needed in one hundred pound lots and carefully sifted to remove all lumps and foreign material. A detailed account of the nature of the various substitutes and the results obtained with each, is given in the following pages. A summary of the work appears on page 49 .

Calf Meal No. 1, composed of:

Ground rolled oats	45 lbs.
Soluble blood flour	20 "
Linseed meal	10 "
Corn starch	14 "
Corn sugar	5 "
Alfalfa flour	5 "
Calcium chloride	½ "
Salt	½ "
Total	100 lbs.

The chief source of protein in this meal was soluble blood flour, a high grade product, readily soluble in water, specially prepared for animal feeding by the United Chemical and Organic Products Company of Chicago. The rolled oats and linseed meal were used because experience has shown that they are of great value in calf feeding. The starch and sugar furnished a large part of the carbohydrate of the ration, and in addition the sugar gave the meal a sweet taste. Alfalfa flour was included as a desirable source of vitamines and protein. Calcium chloride furnished additional calcium in a readily soluble form.

Seven calves were raised on this meal, a group of four during the winter of 1921-22, and another group of three in 1924. The first group made an average daily gain of 1.25 pounds, and required 284 pounds of dry feed for 100 pounds of gain. Strangely enough the second group did not do nearly so well, making an average daily gain of 0.57 pound and requiring 494 pounds of dry feed for 100 pounds of gain. Two of them (Nos. 73 and 74) made so little growth and were so unthrifty that at three months of age they were changed over to Meal No. 6 (see page 47 for composition of this meal) to see if it would produce any more favorable results. No. 73 responded at once and made an average daily gain of 1.28 pounds during the fourth month of his life, as compared with 0.42 pound daily gain previous to the change. No. 74 did not respond at all and had to be put on a skim-milk diet to save him. No reason other than individual vigor of the calves can be assigned for the great difference in the two groups. With one possible exception all of them were strong and hearty when dropped. The figures for the whole lot are: average daily gain—0.96 pound; dry feed required for 100 pounds of gain, 374 pounds.

Calf Meal No. 2 consisted of:

Ground rolled oats	45 lbs.
Skim-milk powder	20 "
Linseed meal	10 "
Corn starch	14 "
Corn sugar	5 "
Alfalfa flour	5 "
Calcium chloride	½ "
Salt	½ "
Total	100 lbs.

This meal was similar to Meal No. 1 except that its chief source of protein was third grade skim-milk powder obtained from the Merrell-Soule Company, Syracuse, New York. Four calves were raised on it and all made good growth, the average daily gain being 1.19 pounds; dry feed required for 100 pounds of gain—316 pounds.

Calf Meal No. 3, composed of:

Ground rolled oats	35 lbs.
Soluble blood flour	5 "
Skim-milk powder	15 "
Linseed meal	10 "
Corn starch	19 "
Corn sugar	5 "
Alfalfa flour	10 "
Calcium chloride	½ "
Salt	½ "
Total	100 lbs.

This meal combined the chief protein sources of Meals 1 and 2; also the starch and alfalfa flour were increased five pounds each, the rolled oats being reduced ten pounds. This change was made for two reasons, (1) it was thought that the alfalfa flour constituted an excellent source of vegetable protein, of vitamines, and of ash, and (2) for the sake of economy. At the time the meal was formulated rolled oats was selling for four cents a pound while starch was less than two cents a pound and alfalfa flour was two and a half cents.

Four calves were raised on this meal; two others did not thrive on it at all and it was deemed best to dispose of them. Of the four raised, two did reasonably well and the other two made very poor growth. The average daily gain was 0.77 pound and the dry feed required for 100 pounds of gain was 349 pounds. It is evident that this meal was not suitable as a skim-milk substitute. Thinking that the trouble might have been due to the increase in amount of alfalfa flour, this ingredient was cut down to five pounds, the amount used in Meals 1 and 2, and the rolled oats increased to forty pounds. The corn sugar was discontinued and five more pounds of corn starch substituted for it. The meal, which was designated as Calf Meal No. 3 (modified), then consisted of:

Ground rolled oats	40 lbs.
Soluble blood flour	5 "
Skim-milk powder	15 "
Linseed meal	10 "
Corn starch	24 "
Alfalfa flour	5 "
Calcium chloride	½ "
Salt	½ "
Total	100 lbs.

Three calves were raised on this modification of Meal No. 3. They made slightly better growth than did those on the original meal, but required considerably more food for an equal amount of gain. The average daily gain was 0.89 pound, and the dry feed required for 100 pounds of gain was 381 pounds.

Calf Meal No. 4 was composed of:

Ground rolled oats	14 lbs.
Soluble blood flour	10 "
Skim-milk powder	10 "
Linseed meal	10 "
Coconut meal	10 "
Peanut meal	10 "
Milk sugar	30 "
Alfalfa flour	5 "
Calcium chloride	½ "
Salt	½ "
Total	100 lbs.

The principal difference between this meal and the preceding ones is in the source of the carbohydrates. In an attempt to more closely resemble milk, milk sugar was substituted for all of the starch and part of the rolled oats. Also ten pounds each of coconut and peanut meal were included to give a higher fat content and in the case of coconut meal to supply more of Vitamines "A" and "D."

Four calves were raised on this meal and, taking into consideration the fact that three of them were delicate to begin with, they made very fair growth, the average daily gain being 0.99 pound, and the dry feed required for 100 pounds of gain being 303 pounds. At prevailing prices of milk sugar this meal was too expensive, but it indicated possibilities which should not be disregarded.

Calf Meal No. 5:

This meal was not prepared to feed as a gruel, but as a dry grain for the control lot of calves which received skim milk, and was not consumed in any quantity until they were 5 to 6 weeks old. It was also fed as dry grain for two lots of calves that received modified skim milk as the liquid portion of their diet. It was composed of:

Ground whole oats (not rolled)	30 lbs.
Flour middlings	20 "
Corn meal	19½ "
Linseed meal	10 "
Coconut meal	10 "
Peanut meal	10 "
Salt	½ "
Total	100 lbs.

Results secured in feeding this meal will be discussed under the heading of skim milk and modifications of skim milk.

Calf Meal No. 6:

This meal was formulated as a result of our experience with the other meals over a period of two years. It consisted of:

Ground rolled oats	20 lbs.
Soluble blood flour	10 "
Skim-milk powder	10 "
Corn starch	19 "
Red dog flour	15 "
Linseed meal	10 "
Coconut meal	10 "
Alfalfa flour	5 "
Calcium chloride	½ "
Salt	½ "
Total	100 lbs.

It is in many respects similar to Nos. 1, 2 and 3. Red Dog flour was substituted for a portion of the rolled oats for considerations of economy and to make a little more variety. Coconut meal was included for the same reason as in Meal No. 4. Peanut meal was not included because of difficulty in obtaining it.

Six calves were raised on this meal. None of them made very good growth at first. Later four of them did very well, but two of them (67 and 68) continued to do so poorly and refused so much of their feed that it was decided to remove from the meal for these two, the coconut meal, which it was thought might be the particular ingredient they objected to. After this change they made somewhat better growth. The average daily gain for all six was 1.02

pounds, and the dry feed required for 100 pounds of gain averaged 326 pounds. As already noted (p. 45) Calf No. 73 when changed from Meal No. 1 to this meal showed a marked improvement in growth.

Skim Milk.

As a standard with which to compare results from our numerous substitutes skim milk was fed to six calves. The maximum amount fed to any one calf was 12 quarts daily. The calves were all weaned to skim milk during the second week of their lives, except that two quarts of whole milk were given daily until eight weeks of age in order to supply a little milk fat. Additional mineral matter was supplied in the form of mineral mixture No. 1 (one part, by weight, salt, to two parts calcium carbonate), three grams of this mixture being added to each quart of skim milk fed. The calves were taught to eat dry grain in the form of Meal No. 5 when about 4 to 5 weeks of age.

All six calves made excellent, some of them phenomenal growth, which was to be expected. The average daily gain was 1.68 pounds; one calf made daily gains of over two pounds. The amount of dry feed required for 100 pounds of gain was 251 pounds.

Skim-milk powder and corn starch.

The dried milk industry has of recent years developed very rapidly. According to Hunziker* there were forty-seven concerns producing skim-milk powder in the United States in the year 1919, and their total output was over thirty-three million pounds. A considerable quantity of the output is so-called "third grade," unsuited for domestic or bakers' consumption but suitable for animal feeding. This can be had at a reasonable price and as it solves the transportation and storage problems of liquid skim milk its value for calf feeding is worthy of thorough study. As already noted we have used more or less of it in all our formulae, as high as 20 per cent in Meal No. 2. During the summer of 1923 a somewhat different method of feeding it was given a trial.

A gruel consisting of two parts of skim-milk powder to one part of corn starch was fed to seven calves, the maximum amount to any one calf being nine quarts of the gruel. The corn starch was added to the milk in order to widen the nutritive ratio, and thus protect the protein from being used as a source of energy.

The weaning procedure and other details were identical with those followed for the calves raised on Meals 1 to 6 except that two quarts of whole milk were fed daily until the calves were eight weeks old. The dry grain for this lot and the next one was Meal No. 5. The gruel was prepared in the following manner:

3½ ounces skim-milk powder
1¾ ounces corn starch
1/10 ounce mineral mixture No. 2 (equal parts by
  weight salt and calcium carbonate)
1 quart water.

The skim-milk powder and starch having been weighed out beforehand, the necessary amount of cold water was measured out and the starch stirred into it slowly and carefully, care being taken to have all lumps broken up. The starch and water mixture was then heated slowly and with constant stirring to a temperature about 170°-175° Fahrenheit, but not higher than 175° Fahrenheit. The mixture was then cooled to 140° Fahrenheit and the skim-milk powder and mineral mixture slowly stirred in. When the gruel had cooled to blood heat it was ready to feed. This method of preparation insured a uniform gruel free from lumps, and the solids did not settle out on standing. Several gallons of the mixture were made up at one time and it kept well, being quite sweet twenty-four hours after mixing if kept cool. The calves drank the gruel readily and although they had some digestive disturbance in the form of scours this was not any more marked, nor as much so as in the case of many of those raised on the different meals. All of them made good growth, notwithstanding the fact that four of them were delicate at birth. The average daily gain was 1.34 pounds and the dry food required for 100 pounds of gain was 280 pounds.

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*Otto F. Hunziker, Condensed Milk and Milk Powder, 3d edition, 1920, p. 278.

Liquid skim milk and starch.

In order to check the skim-milk powder against liquid skim milk, a second lot of four calves was fed on a gruel prepared in a manner similar to the above except that liquid skim milk was used, the starch and mineral mixture being stirred into the skim milk which was then heated to about 150° Fahrenheit, not higher. All the calves made very good growth, the average daily gain being 1.35 pounds, and the dry feed required for 100 pounds of gain was 277 pounds, results almost identical with those obtained in feeding the skim-milk powder and starch. This would indicate that skim-milk powder can be successfully substituted for the liquid article.

The question was raised as to whether the calves could readily assimilate the starch added to the skim milk. The good growth secured with both lots of calves (eleven in all) indicates that they were able to utilize it quite well. Tests for starch were made on their droppings. In only two instances was any found, and both of these were delicate calves at birth.

The accompanying table summarizes the results which have been given in detail in the foregoing pages.

SUMMARY OF GAINS PRODUCED ON VARIOUS SKIM-MILK SUBSTITUTES

Material	Number of calves	Average daily gain in live weight	Average amount dry feed for 100 lbs. gain	Cost of food per 100 lbs. of gain	Food cost to 4 months of age	Cost of one quart of gruel	Cost of 100 lbs. of dry calf meal	Remarks
		Lb.	*Lbs.*			*Cts.*		
Calf Meal No. 1....	7	0.96	374	$15.39	$22.56	1.6	$6.30	1st lot did well 2d lot did very poorly
Calf Meal No. 2....	4	1.19	316	14.39	20.58	1.3	5.10	Made good growth
Calf Meal No. 3....	4	0.77	349	16.55	15.72	1.4	5.40	Did not grow very well
Calf Meal No. 3, modified	3	0.89	381	18.17	19.80	1.4	5.40	Slightly better gains than those on Meal 3
Calf Meal No. 4....	4	0.99	303	22.67	27.19	2.4	9.90	Made very fair gains
Calf Meal No. 6....	6	1.02	326	15.62	19.32	1.3	5.10	Made very fair gains
Skim milk (check lot)	6	1.68	251	(14.29* (16.91†	28.54	1.6‡	....	Excellent growth
Skim milk and starch	4	1.35	277	17.67	29.25	2.0‡	....	Very good growth
Skim milk powder and starch	7	1.34	280	20.32	33.38	2.5‡	....	Very good growth

*With skim milk at 1½ cents a quart.

†With skim milk at 2 cents a quart.

‡The dry grain fed to these three lots was Meal No. 5, which cost at current prices approximately $2.50 a hundred. All costs are figured from prices current in September. 1924.

Discussion of the Results.

In the first place the results of the several trials, as summarized in the preceding table, confirm our previous knowledge relative to the superior value for growth of skim milk for young calves, providing it can be had at a reasonable price (1.5-2.5 cents a quart). Even at 1.5 cents a quart, the food cost of growing calves to four months of age is considerably above that of the calf meals; but *on the basis of growth produced,* the food cost is about the same as for the several meals. Only, however, when liquid skim milk is not available at such prices should calf meals or skim milk powder be substituted.

In the second place our studies show that calves can be raised on various skim milk substitutes together with a minimum of skim milk, and fairly good growth secured. Care has to be taken not to overfeed. Many of the calves thus grown are apt to look rather rough and not as smooth as skim milk calves. After they have reached the age of 6-8 months this difference generally disappears. The average amount of skim milk consumed by the calves raised on the various meals was 211 quarts, as compared with an average consumption of 1046 quarts by the calves in the check lot which were raised on skim milk and dry grain and hay. Those fed skim milk and starch consumed on an average 912 quarts of skim milk. The calves reared on Meal No. 6 received an average of only 108 quarts of skim milk each.

It must be admitted that the dairyman who raises a few calves at a time, if he does not have skim milk available, will have to depend upon the manufacturer for his calf meal mixtures. The manufacturer can secure and blend the different ingredients more cheaply than the small feeder; hence the results of station studies along this line are likely to be passed to the dairy farmer through the manufacturer.

The work has shown quite conclusively that skim-milk powder is a promising substitute. This material is fairly easily obtained, can be readily prepared for feeding, and at present prices costs very little more than liquid skim milk. The addition of starch spares the amount of milk powder, but slightly increases the cost of the gain. Because in the processes of drying the skim milk, it is heated to 140° Fahrenheit or above for a considerable time, it would appear that the danger from disease germs is likely to be remote.

Finally it may be remarked that success in calf rearing is dependent not only on the feed used but on several other factors which are:

(a) A vigorous calf at birth.
(b) Clean pens and clean feeding utensils.
(c) Regular feeding hours.
(d) Special attention to the individual peculiarities of each calf.
(e) Milk or gruel always fed at the same temperature—blood heat or thereabouts.
(f) Care to prevent overfeeding. If the calf refuses part of his allowance let him go hungry at the next meal, or if he starts to scour cut his ration in half for the next twenty-four to thirty-six hours.
(g) Sunshine, fresh air and exercise. Access to pasture if possible after the calf is six months of age; at least an open yard to run in, except in severe winter weather.

The above bulletin is a report of progress only. The study of skim-milk powder and of milk substitutes for young calves is being continued along somewhat different lines and any pronounced progress will be reported.

Practical Suggestions.

On the basis of the work reported in this bulletin, we are not prepared to recommend any particular combination of ingredients going to make up a calf meal mixture. Combinations No. 2 (see page 45) and No. 6 (see page 47) have done fairly well. As already stated, the most promising substitute investigated has been skim-milk powder and a combination of the powder with corn starch.

If skim-milk powder is used as a substitute for liquid skim milk, it is suggested that one pound of the powder and a scant even teaspoonful of salt be fed to each gallon of water. The milk powder and salt should first be stirred with a small quantity of cold water to avoid lumping and after a creamy consistency has been secured the necessary amount of lukewarm water should be added, the mixture well stirred and thus fed. Do not feed the solution cold.

If skim-milk powder and starch are fed, mix as follows:

1 lb. of dry skim milk
½ lb. of corn starch
Level teaspoonful of salt.

Five ounces of this mixture should be added to each quart of water. The method of mixing consists in adding to the powder a small quantity of cold water and thoroughly stirring in order to avoid lumping. After a creamy consistency is secured, add the necessary water, stir and heat the mixture to 150° Fahrenheit and allow it to cool to blood heat before feeding. An amount sufficient for one or two days can be mixed at one time, but before feeding, it should be well stirred and heated until it is lukewarm.

COMPOSITION OF CALF MEALS

Material	Water	Dry Matter Basis*				
		Ash	Protein	Fiber	Nitrogen-free Extract	Fat
Calf Meal No. 1..................	9.92	4.27	32.24	2.61	56.62	4.28
Calf Meal No. 2..................	8.93	4.75	18.12	2.51	70.10	4.52
Calf Meal No. 3..................	8.56	4.98	21.87	2.68	67.00	3.46
Calf Meal No. 3, modified.........	9.76	4.67	22.40	2.42	65.98	4.52
Calf Meal No. 4..................	6.49	4.68	27.35	3.84	59.40	4.73
Calf Meal No. 5..................	10.18	4.40	21.02	6.71	61.07	6.79
Calf Meal No. 6..................	10.71	5.22	24.64	3.54	61.88	4.72
Skim-milk powder and starch gruel	88.90	8.05	20.72	none	71.26	trace
Skim milk and starch gruel.......	88.70	6.99	18.58	none	74.42	trace

*In case of the dry meals to reduce roughly to normal water basis, deduct 10 per cent, and for the skim milk and starch gruels, deduct 90 per cent.

A study of the chemical composition of the several meals shows that they contain, when ready to feed, about 10 per cent of moisture, 4-5 per cent of mineral matter, 2-3 per cent of fiber, 60-70 per cent of extract matter (largely starch), and 4-6 per cent of fat. The protein percentage in the several meals varies widely—from 18 per cent in case of Meal No. 2 to 32 per cent in case of No. 1. We have no positive knowledge as to the best percentage of this ingredient, but on the basis of our experience believe that 18-24 per cent should prove satisfactory. The fiber percentage should be kept as low as possible, especially in a meal that is to be used in the gruel form during the first few months of the life of the calf. A reasonable amount of fat is desirable. It is doubtful if 5 to 7 per cent is at all excessive.

6000. 4-7-'25. Order No. 1473.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 224 March, 1925

THE COSTS OF MARKETING THE APPLE CROP OF 1923

By Lorian P. Jefferson

Knowledge of costs is a necessary antecedent to control over them. Increasing competition from other producing regions makes it necessary that Massachusetts orchardists know their costs, and be prepared to reduce them, or to give better marketing service, in order to maintain the strategic position which is and should continue to be theirs. The study which this bulletin reports was initiated, therefore, as an attempt to determine the factors of cost which Massachusetts orchardists must meet in getting their product from the tree to the market which they serve.

Requests for bulletins should be addressed to the
AGRICULTURAL EXPERIMENT STATION,
AMHERST, MASS.

5,000. 4-24-'25. Order No. 1620.

THE COSTS OF MARKETING THE APPLE CROP OF 1923

By LORIAN P. JEFFERSON

This study was undertaken in order to determine the costs of putting apples on the market, what grades may be marketed with profit, the margin over costs of marketing returned to the grower from sales by various methods, and the type of container most desirable.

Information was collected by personal visits to growers, 65 individual reports being obtained beside that from the Nashoba packing house.

No attempt was made to secure data from all growers in any section, but those growers visited were representative. Data were obtained in four sections of the state—Franklin County; Granville, a small and comparatively new area near the Connecticut line in Berkshire County; the Newbury section in the northeastern corner of the state; and an extensive area centering about Littleton, but including many widely scattered growers of Middlesex and Worcester Counties.

The data used were sometimes taken from records, bills of sale, etc., kept by the grower, and sometimes—more often indeed—they were thoughtful estimates of the producer. Most of those visited gave such estimates for at least a part of the information sought, although many had some sort of record on which the figures were based. These figures were carefully tabulated, omitting the few questionable returns.

It was found that, owing to wide ranges in the reports, averages were not always representative of the expenditures for various items. In these cases the most common cost was used as typical. Hence the tabulation summarizing the costs must be considered merely as a fairly representative list of costs. All averages are weighted except when otherwise stated.

No attempt was made to discover the cost of growing the fruit. It must therefore be recognized that the "margins" or "returns" considered throughout the study are to be regarded as profits only after the costs of growing are deducted from the "margin over cost of marketing."

One grower said that apples could not be sold at a profit unless the price obtained was more than $3.50 a barrel. Another said that it cost $2.00 to grow and market a bushel of apples. Obviously a wide range exists in the individual costs of production as well as in the costs of marketing. A difference of 83 cents a bushel appears between the two cases cited.

Grades.

The law of the state provides for three grades of apples—Fancy, A and B—and an ungraded class. In reality, the apples known as ungraded are of two kinds: those which are sold as they come from the trees, culls only having been removed; and the inferior grade which remains after Fancy, A and B grades—any or all of them—are taken out. The term "ungraded" as applied to this inferior lot of apples is a misnomer, and some other designation should be devised.

The growers visited reported 214,153 bushels of apples sold from the crop of 1923. Seventy-five per cent of these were sorted and graded. The grades appeared in the following proportions:

Grade	*Bushels*		*Per Cent*	
Fancy	17,640		8.1	
A	68,816		32.1	
B	29,273		13.7	
Ungraded	90,062		42.0	
True		52,007		24.3
Inferior		38,055		17.7
Cider	8,362		3.8	

Of the apples which were graded, 13 per cent were Fancy; 51 per cent were A's; 22 per cent were B's; while 14 per cent were the inferior stock, called "ungraded," left after the higher grades were sorted out. Some few of the growers graded into all grades, but most of them did not. Sixteen per cent report apples of the Fancy grade; 41 per cent sold apples of A grade; 27 per cent sold B grade; and 17 per cent sold ungraded stock which remained after the higher grades had been sorted out.

Methods of Sale.

Probably the most important single factor in determining the price received for apples is the method of sale. Obviously, whether the highest price means also the greatest profits depends upon costs of production and costs of marketing.

Several methods of sale were found in current use among the growers visited:

1. To the buyer, who comes to the orchard or packing shed, usually provides his own containers, and may be a huckster, a jobber or a wholesaler. This method is common throughout the state.
2. To the wholesaler, to whom the apples are usually delivered by the grower.
3. On commission, the rate of commission varying from 7 per cent of the selling price for apples which are exported, to 12 per cent which is the common rate on the Worcester market.
4. To the retailer, the grower generally paying the delivery charges, although in at least one instance the retailer buys the entire crop of the grower and hauls it away on his own trucks, a distance of 30 miles.
5. Cooperatively, there being one cooperative packing association and one cooperative roadside market selling apples.
6. At retail, at the door or at a roadside market maintained by the grower.
7. From door to door, probably the most expensive method of sale.
8. At a farmers' market. One grower only reports sales by this method and his fruit is sold chiefly to retailers and hucksters.

Sale to buyers who come to the door is probably the most common way of selling throughout the state, 55 per cent of the growers visited selling all or part of their crop to buyers at the door. Some of the buyers are hucksters and sell in various cities throughout the state. Some are wholesalers and some few are retailers. Frequently the fruit is bought "orchard run" at the farm and the grower has no responsibility for it after it is picked and hauled from the orchard. Most of these buyers seem to make the best bargain possible with each individual grower, having neither fixed price nor fixed terms of purchase, and these terms may differ widely in any community. Particularly is this true in the western part of the state. One grower sells his apples on the trees, the buyer picking, sorting and packing them and hauling them to the station. Another grower picks his apples, hauls them to the packing shed, supplies one packer, while the buyer supplies one or two. Sometimes the grower furnishes two or three packers and boards another who is hired by the buyer. The grower may or may not deliver the apples f.o.b. his loading station.

The same variations appear in the prices paid by these buyers, who sometimes request the growers not to reveal the price paid. The range of prices for the different grades of the crop of 1923 varied as follows:

A	$3.00 to $5.00, per bbl. with eight different prices.
B	$2.75 to $3.60, per bbl. with five different prices.
Ungraded	$1.00 to $4.00, per bbl. with twelve different prices.

More than half the apples reported for this study by Franklin County growers are sold absolutely ungraded; while but 6 per cent are sold as the inferior lot, misnamed "ungraded," remaining after the better grades are sorted out.

With the exception of those who sold their apples on the tree, the growers who sold to these buyers always paid two items in the cost of marketing—picking and hauling from the orchard to the packing shed. From this point, varying bargains were made by the buyers. They did all or any part, commonly one-half, of the sorting, grading and packing; they furnished the container in some cases, while in others it was furnished by the grower; either the buyer or the grower hauled to the station, as was agreed. The freight was generally paid by the buyer.

The reasons for this undesirable situation seem to be:

1. The distance from market. Most of the orchards lie at a considerable distance from the large markets in the western part of the state, and the small markets are soon over-stocked. The haul to Holyoke or Springfield is long—40 miles at the least, and for some of the growers it is 50 miles or more. On account of the hills this haul is more difficult than one of the same mileage in a more level section. It is more convenient and less expensive to sell to a buyer at the door, or at least at the nearest shipping point.

2. Custom undoubtedly has some influence in the matter. For years these buyers have come to Franklin County for the apples they handle, and the growers have formed the habit of selling by this method.

3. The size of the individual crop probably influences to some extent the method of sale. The average crop in Franklin County is about 2200 bushels, and 45 per cent of the growers reporting sell yearly less than 1700 bushels each. The average crop in the eastern section of the state is nearly twice as large as that in the Franklin County area.

In Worcester and Middlesex Counties the methods of sale are various, but chiefly apples are sold to buyers at the farm, cooperatively, to retailers, and on commission. The most interesting method is the cooperative sale by the Nashoba Apple Packing Association, which maintains two packing houses, one in Littleton and one in Bolton.

The apples were picked and hauled from the orchard by the grower. They were hauled to the packing house by the Association at a flat rate of 5 cents a bushel, regardless of distance. Sorting, grading and packing costs were reported as 30 cents a bushel, but this included some items which should have been charged to supplies. The actual cost of the labor of sorting, grading and packing was possibly not more than 25 cents a bushel.

The packed box was then hauled to Boston for 12 cents and delivered to one commission merchant who handled the entire output of the Association.

There was a very small charge for labels and advertising. With commissions the total costs of the Association amounted to an average of $1.08 per box.

Over half, 51 per cent, of the growers report that they sell by one method only; 27 per cent sell by two methods; 18 per cent use three methods, while four, five and six methods are used by one grower each.

Two growers sell their crops on the tree and have no further responsibility.

Buyers who come to the orchard purchase the entire crop of 30 growers reporting. Nine growers sell to wholesalers, 20 on commission, 23 to retailers, 7 to hucksters, 7 cooperatively, 9 at retail at the door or at roadside stands, 6 sell from door to door, and one at public market.

Total Costs.

The items of cost which appear in the marketing of apples may be listed as follows, but it is obvious that very few growers would incur each of these expenditures:

Picking
Sorting
Grading
Packing
Container
    Boxes, with risers
    Barrels
    Baskets
Cooperage

Heading of barrels
Nailing of boxes
Paper
Hauling container to orchard
Hauling container to packing shed
Hauling from farm to market
Hauling from farm to station
Hauling to storage
Hauling from storage
Freight
Storage
Selling

It will be noted that the costs of marketing are here considered as beginning with the cost of picking and including all actual expenditures till the fruit is in the hands of the first purchaser, whether he be buyer, wholesaler, retailer or consumer. These costs vary greatly with different growers and to a certain extent with the locality.

Picking.

The most common cost of picking a bushel of apples, as reported by the producers visited, was about 8 cents in 1923. The range of costs for this operation was from 3 cents to 20 cents. Of the 62 reporting, 31 paid less than 10 cents a bushel for picking, 14 paid from 10 to 14 cents, and 17 paid from 15 to 20 cents. The average cost was between 10 and 11 cents a bushel.

Sorting.

Sorting, grading and packing costs vary even more widely than the picking costs, the range being from 3 cents to 42 cents a bushel. The average cost was 13 cents; 43 per cent of the growers report this charge as less than 10 cents, 31 per cent paid between 10 and 14 cents, 11 per cent paid between 15 and 20 cents, while 13 per cent report that it cost more than 20 cents a bushel. The most common cost was 8 1/3 cents.

It must be recognized that these figures include all types of sorting, grading and packing; those that are merely put into the container as well as those that are sorted, graded, wrapped and packed, the utmost attention being given to each detail. Obviously there must be wide differences between costs. Fourteen per cent of the apples sold (ungraded) were reported as having cost an average of 5 cents a bushel for such sorting and packing as was done. This is 37 cents less than the highest charge reported.

Storage.

Comparatively few growers stored apples and only 15 of these were able to give costs of storage. The range of this charge was from 3 cents to 32 cents a bushel, but includes farm storage as well as hired cold storage, the farm storage being estimated on the basis of interest on the cost of the storage. The average cost of storage per bushel of apples stored was 23 cents. This average is much increased by the costs of a few growers, as one-third of those reporting storage costs paid less than 10 cents a bushel.

Containers.

More than half the costs of marketing apples in Massachusetts may often be charged to the container. The average price of barrels to 45 growers, who sell in this way, amounts to 23 cents per bushel sold. The prices reported ranged as high as 85 cents a barrel including cooperage and delivery. Some growers buy second-hand barrels when these are obtainable, and some report that the barrels are returned by the retailer or the consumer.

Boxes cost an average of 21 2/3 cents as reported by 30 growers, and the most common price is 22 cents. Baskets are reported in several sizes, holding

2 quarts, 4 quarts, 8 quarts, 14 quarts, 28 quarts, a half-bushel and a bushel. The cost of baskets averages, for the 23 growers who report their use, about 26 cents a bushel.

The one grower who reported sales in 2-quart baskets paid at the rate of 48 cents a bushel for these containers. Four-quart baskets cost an average of 32½ cents a bushel. Selling in baskets containing 14 quarts meant an average expenditure of 23 cents a bushel for containers, while baskets holding 28 quarts cost an average of 17 cents a bushel. Baskets containing a bushel cost an average of 13 cents.

One instance was found where the containers, "barrel crates," were the property of the buyer, who charged the grower 25 cents each for their use. The grower had, however, provided storage space for these crates between seasons, and for this service the buyer allowed him 12½ cents per crate. This amounted to nearly 3 cents a bushel cash outlay for containers.

The type of container most desirable seems to depend upon the grading done. Ungraded apples are probably more suitably packed in barrels, while graded fruit may better be packed in boxes. Baskets seem to be used for retail trade particularly.

Selling Costs.

The cost of selling varies greatly with the method of sale. The most expensive methods being, apparently, from door to door and at roadside markets, but accurate data as to these methods are very difficult to obtain. Quantities thus sold vary from day to day with a consequent change in selling costs per unit.

Selling on commission is most commonly at a rate of 10 per cent of the selling price, although exported apples are sold for 7 per cent commission, and rates here run as high as 15 per cent. Sales in Worcester are reported at 12½ per cent. The average cost of selling on commission was 19 cents a bushel.

The selling costs of 106 lots of apples sold varied from 4 cents to 90 cents a bushel. The most common cost was 10 cents a bushel, 11 per cent of the lots reported showing this selling cost. The average cost of all these lots was 18 cents a bushel.

There were in addition 36 lots, most often the entire crop, sold to buyers who came to the door, relieving the grower of all selling costs except for the time required to bargain with the buyer. For the purpose of this study, there is no cost of selling included for the lots of apples so sold.

The average selling costs on all lots reported, 142 in number, was nearly 14 cents a bushel, but this figure has little significance in view of the wide variation in individual costs. The weighted average selling cost was 18.6 cents per bushel.

Transportation.

The cost of hauling from orchard to packing shed is most commonly about 2 cents a bushel, 34 per cent of the growers reporting this cost, while 77 per cent report a charge of less than 5 cents a bushel for this item. The highest cost reported is 12½ cents a bushel.

More of the crop is hauled to market by truck and wagon than is shipped by freight. The cost of hauling to market ranges from 3 cents to 33 1/3 cents. The most common cost is 15 cents; 42 per cent of the growers report this cost to be either 15 or 16 cents, while 39 per cent haul their apples to market for less than 15 cents a bushel.

The most common cost of delivery at the station is 5 cents a bushel, the range being from 5 to 11 cents.

Two-thirds of the growers use motor trucks, mostly privately owned, but a few are hired. The average length of haul by truck is 20 miles, practically always to market, though a few haul by truck to their railroad stations, delivery being thence made by freight. Wagons are used by the remainder of the growers, and three report that they use both, depending upon the weather. The average wagon haul is 4 miles and the haul is commonly to the station.

A few, however, report that apples are hauled by wagon to nearby markets. Wagons are used almost entirely in the western part of the state where the hills sometimes render hauling by truck a difficult matter.

The average haul for all vehicles is about 15½ miles, while the most common haul is less than 10 miles. The average haul by wagon is about 4 miles at an average cost of $.0169 for hauling one bushel one mile. The average haul by truck is 20 miles, at an average cost of $.0092 a mile for each bushel hauled.

The mileage cost per bushel hauled by truck less than 10 miles is $.0136, nearly ¼ cent less than by wagon.

For distances varying from 10 to 24 miles, the trucking cost per bushel averages $.009 per mile, while for distances of 25 to 43 miles (the greatest reported) the average cost is $.0053 per bushel per mile.

The most common cost for trucks lies between ½ cent and 1 cent per mile for a bushel, while the most common cost for wagons lies between 1 cent and 1½ cents. One-fifth of the trucks carry a bushel a mile for less than ½ cent, while 8½ per cent report cost exceeding 1½ cents a mile for each bushel hauled. The highest cost reported was slightly more than 5½ cents, which appears in both truck and wagon costs. The lowest cost was reported for a truck hauling a distance of 30 miles for 15 cents a barrel, $.0016 a bushel per mile. The most common length of haul by truck was 30 miles at an average cost of $.0058 per bushel per mile. The average cost for all vehicles is practically one cent a mile for each bushel handled.

Transportation costs for trucks amounting to nearly the same figure are reported from the eastern and western parts of the state. Few wagons are used in the eastern section, except for hauling from the orchard to the packing shed.

Cider Apples.

Cider apples included culls and apples from wild trees unfit for other use. These were sold mainly at local cider mills, although some few growers make and sell their own cider. Cider apples brought an average price of about 17 cents a bushel, but they are sold mostly by the hundredweight.

Prices and Margins.

Following is a comparison of the prices and margins over costs of marketing received for the various grades by different methods of sale. The three methods most commonly employed among the growers visited are here presented, since the great part of the apples reported were sold by these methods.

It is notable that in every case sales to country buyers showed the lowest prices and lowest margins over costs of marketing. Sales of Fancy apples to retailers brought the highest margins over costs of marketing. Sales of A's on commission brought the highest price for this grade, and sales on commission averaged the highest prices and the highest margins.

The true ungraded apples brought the highest prices for this grade when sold on commission, but a small quantity of inferior ungraded sold to a retailer brought the highest margin over costs for this grade. This was due to the fact that the retailer supplied the container and hauled the apples from the farm, making the actual expenditures of the grower very small. However, the price received was not as high as for those of the same grade sold on commission. Ungraded apples returned lower prices and margins over costs of marketing by all methods of sale than did graded fruit.

The influence of low grades of a product upon the prices received for the higher grades is difficult to calculate, but it is the opinion of many growers and dealers that the low grade apples might be kept off the market with profit to the grower. It is doubtful, for example, if the margins over the costs of marketing ungraded apples, when sold to country buyers particularly, cover costs of production. In 1923 it is certain that some growers lost on B grade apples, and others made little or nothing by selling this grade. Some few growers made their low grade apples into cider which was sold at a roadside market.

Average Prices, Costs of Marketing, and Margins over Costs of Marketing.

	Bushels	*Average Price*	*Cost of Marketing*	*Margin over Cost of Marketing*
FANCY				
To country buyer	1,224	$1.67	$ .53	$1.14
To retailer	180	2.12	.38	1.74
Commission	9,636	2.07	.45	1.62
A GRADE				
To country buyer	14,697	1.23	.49	.74
To retailer	13,824	1.93	.81	1.12
Commission	18,495	2.20	.98	1.22
B GRADE				
To country buyer	3,594	1.34	.60	.74
To retailer	5,280	1.51	.63	.88
Commission	9,201	1.56	.88	.68
UNGRADED—INFERIOR				
To country buyer	12,535	.91	.41	.48
To retailer	225	1.08	.10*	.98
Commission	19,414	1.90	1.06	.84
UNGRADED—TRUE				
To country buyer	27,980	.88	.39	.49
To retailer	8,300	1.10	.40	.70
Commission	2,000	1.92	.84	1.08

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*Sold at door, buyer furnishing container and hauling away.

A comparison of the prices and margins over costs of marketing for all graded apples and for those ungraded which are merely picked, sorted and packed is of interest. All graded apples, including the so-called ungraded remaining after other grades are removed, brought an average price of $1.79 per bushel, with an average margin of $1.03. The true ungraded apples brought an average price of $1.03 with a margin over costs of marketing of 57 cents a bushel, practically half the margin on all graded apples. Omitting the inferior grade, the graded apples brought an average price of $1.88 with an average margin of $1.08 per bushel.

According to the data tabulated, B grade apples sold to country buyers brought a higher average price than did A's sold by the same method. This may be explained by the fact that comparatively few apples of B grade were sold by this method, tending to give undue weight to any unusual instances; and that some lots of apples brought the same price for A and B grades.

In the case of ungraded apples, it is noticeable that the country buyer paid more for the inferior class than for the true ungraded. This may, perhaps, be explained by the probability that the growers who grade their apples carefully do so because they are better acquainted with market conditions and are therefore in a position to make a better bargain with the buyer.

Information secured with reference to the expenditure of labor necessary to pick, sort, grade and pack showed that there is a wide variation in labor as in money costs. The average number of bushels reported picked in a day is about 48, although orchard conditions have a marked influence in the matter. Sorting, grading and packing, which are usually considered as one item, average a little higher, one worker packing about 54 bushels a day. Many growers, however, estimated that the labor costs of this item are about the same as for picking.

It is almost impossible to give the cost in labor of other items, such as hauling and storing, because the work is done so intermittently that the amount of time required per bushel or the amount of work done in a day is difficult to estimate.

A tabulation of the average or most common expenditures for the various items entering into the costs of marketing will serve as a summary.

Operations	*Cost per Bushel*
Picking	$ .10
Sorting, grading and packing	.13
Container	.23
Hauling from orchard	.02
Hauling to station	.05
Hauling to market	.15
Selling	.19
Typical costs of marketing apples hauled to market	$ .87
Storage	.23
Hauling from storage	.05
Typical costs	$1.15

The study leads to certain definite conclusions.

1. Sale to country buyers is the least profitable method of sale.

2. It pays the grower to grade his apples. How closely this may profitably be done depends, obviously, upon the character of the crop.

3. Sales on commission returned, to the growers reporting, the highest average prices and the highest average margins over costs of marketing. These sales were made in some cases throughout the season, thereby taking advantage of the season of highest prices. The 10,000 bushels sold cooperatively were in this group. Some other methods, *e.g.,* sale to country buyer, dispose of the crop early in the season, when prices are likely to be low.

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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 225 DECEMBER, 1925

YELLOW PICKLE IN GREENHOUSE CUCUMBERS

By VICTOR A. TIEDJENS

Contribution from the

MARKET GARDEN FIELD STATION

of the

MASSACHUSETTS AGRICULTURAL COLLEGE

Yellow pickles on greenhouse cucumber plants are due to a physiological disorder causing the fertilized pickles to ripen prematurely. Any environmental factor that reduces the amount of food material in the plant may result in a condition favorable to the formation of yellow pickles. Inadequate light, insufficient nitrates, excessive set, surplus water, poor drainage, or a serious attack of animal or plant parasites may all contribute to a premature ripening of cucumbers. The remedy is primarily the prevention, elimination, or correction of those conditions that tend to devitalize the plant.

Requests for Bulletins should be addressed to the
AGRICULTURAL EXPERIMENT STATION,
AMHERST, MASS.

YELLOW PICKLE IN GREENHOUSE CUCUMBERS

By VICTOR A. TIEDJENS

Perhaps no other problem causes greenhouse cucumber growers more concern than the appearance of a large number of yellow pickles when the vines should be yielding at their maximum. Whenever plants are weakened from disease, poor growing conditions, or a heavy set, yellow pickle[1] is always present. Some growers attribute it to degenerated seed, some regard it as mosaic, while others ascribe the condition to lack of pollination by bees. Observations on self and cross-fertilized cucumbers for two generations lead to the conclusion that these assumptions are to a certain extent correct, but the condition is due to many more causes than any one group is usually willing to admit.

Yellow pickles may be the result of one or more causes such as too heavy a set, poor pollination, the method of growing (whether string or A trellis is used), insufficient soil nutrients, animal or plant parasites, or conditions that weaken growth and stunt the plant.

The Condition Called Yellow Pickle

Reference is made to yellow pickle as a condition because it is usually secondary and is brought on by one or more causes. As a rule yellow pickle manifests itself on small cucumbers on old diseased vines, or heavily set vines which are in the first set. Occasionally the condition is found in cucumbers from six to eight inches long if the plant has experienced a sudden shock or "set back." Ordinarily, in the condition known as yellow pickle, the cucumber does not grow beyond a length of four inches. After growth is stopped the cucumber becomes yellow near the stem end, the yellow color gradually spreading toward the tip if decay does not set in first. Some make sufficient growth to mature a few viable seeds. If sufficient growth has not been made to develop viable seed, the cucumber wilts and gradually dries up.

If it has been fertilized, the yellow pickle may remain on the vine from four to six weeks before it drops off. This condition has been called premature ripening, but differs from that of a normally maturing cucumber in that the yellowing of the mature cucumber becomes visible over the entire surface, the stem end being less pronounced in color than the remainder of the cucumber, a condition directly opposite to that found in yellow pickle. Plants may have from one to six or more of these yellow pickles at one time, depending on the set of the plant. A plant having a heavy set may develop only half of the pistillate flowers into marketable cucumbers, in which case the other half becomes yellow, the proportion of yellow pickles to normal cucumbers depending on the vigor of the plant. A weak plant may mature only one of many pickles fertilized, in which case the percentage of yellow pickle will be very high; whereas, although a strong plant under the best growing conditions may not mature all its pickles if the set has been exceptionally large, the percentage of yellow pickle will be relatively small.

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[1] There is some confusion in the use of the two terms "yellow" and "white" pickle. The condition here referred to as yellow pickle may result from any one of several physiological causes and manifest itself in a premature yellowing of the pickle.

The Relation of Fruit Set to the Development of Yellow Pickle

A cucumber plant grows in cycles with reference to producing pistillate flowers. After a large number of pistillate flowers have been produced, that is, one on each node up to the first ten nodes of the stem, only staminate flowers are produced for a number of new nodes higher up, followed by another group of pistillate flowers. Thus a "set" usually follows the removal of a number of large cucumbers from the vine. Usually more pistillate flowers are produced in one set than the plant will mature, and some of them must be sacrificed. Under greenhouse conditions, where all the flowers are in a favorable position to be visited by bees, a very large percentage of the female flowers set fruit. If conditions are ideal for good growth, the plant may be able to mature a complete set. Usually, however, a few of the cucumbers formed on the first few nodes of the plant are a day or two ahead of the others and develop normally, while the later pollinated pistillate flowers make very little growth until the first formed cucumbers have been picked. If growing conditions are unfavorable so that several weeks are required to grow the market size cucumber, the pickle becomes stunted and, even though conditions later become favorable, it does not grow. Instead a newly pollinated flower may start and as a result the small pickle is prematurely ripened. It may have a few viable seeds or it may not have grown sufficiently to develop any seed. The pickle turns yellow, a condition which many growers have attributed to a parasitic disease. An infection of a plant by an organism is probably the most important cause of yellow pickle on normal plants.

The condition cited above very definitely manifested itself in self-pollinating work on old plants which had set a number of fruits. A study was undertaken of certain characters existing in a mixed lot of cucumbers grown in the station greenhouse. Self-pollinated flowers, on plants already having a number of pickles set, invariably developed yellow pickle; and not until every pollinated flower and developing cucumber were removed from the plant was it possible to get the plant to produce any self-fertilized fruit. On the other hand, when the first flowers of the plant were self-pollinated the fruit developed and matured, indicating that self-pollination was not the determining factor.

Yellow pickle was very much in evidence on plants used for seed production in breeding work. As many as eight pistillate flowers on a plant were selfed, but only three or four matured while the others remained for several weeks without growing, and then turned yellow. It was not uncommon to find five or six yellow pickles on these plants because of the time required to mature the early pollinated fruit.

Since, in the production of seed, the mature cucumber must remain on the vine much longer than that which is picked for market, much more food material is required and the plant is not able to carry as much maturing fruit as if all were picked green. Under such conditions yellow pickle is very much in evidence.

Generally yellow pickle is associated with old vines, but the plants in the above experiment were in their first set. This brought out the fact that yellow pickle is a premature ripening of pollinated flowers at a time when the plant is carrying a heavy load. The second set came along after the mature seed cucumbers were removed. The fruits from this set produced good marketable cucumbers while the yellow pickles were still hanging on the vines. A few that had not turned yellow failed to grow after standing still for such a long time, and finally dried up without becoming yellow. The flowers from which these yellow pickles developed were self-pollinated on June 21, 1925. The pickles did not begin to turn yellow until August 8, 1925, 48 days later. Some of them were three to four inches long and a few had some viable seeds.

Relation of Pollination to the Development of Yellow Pickle

Many cases of yellow pickle can be attributed to lack of pollination. However, with certain varieties, when a pistillate flower is not pollinated, its growing period is much shorter, and the pickle very seldom grows over two inches. Often it does not have the characteristic yellow color found on the larger pickles. In the case of the English variety it is possible to mature large cucumbers without pollination, but this is not the case in the ordinary varieties used in a study of this problem. Yellow pickles were found, however, on English vines which already had three or four mature cucumbers.

Interest in the yellow pickle problem prompted the bagging of a large number of pistillate flowers to prevent visitation by insects. None of these flowers developed pickles over two inches long. The color was a grayish yellow and in some cases almost white. Some of these decayed in a short time, while others dried up and dropped off, a condition differing from that described above.

The Relation of Method of Growing to Yellow Pickle

Two methods of growing cucumbers in greenhouses are generally practiced; namely, the "A" trellis method, and the string method. Where the "A" trellis is used, fewer plants are necessary and these develop more normally than with the string method. With the string method the plants are closer together, and are pruned so that each branch has only one or two nodes, the main stem being twined around the string which extends from a wire near the top of the house to the base of each plant. The prevalence of yellow pickle depends somewhat on the method that is used.

The number of pistillate flowers formed is largely determined by hereditary factors. Thus, there will be as many pistillate flowers on the main stem and first two nodes of the branches whether the plants are grown on strings or trellises. In the string method, a large amount of leaf surface is removed in pruning, thus curtailing the amount of food the plant can manufacture and store. Such plants cannot develop as many of the pistillate flowers as those on the "A" trellis where very little pruning is done. Also, the plants are crowded more in the string method and less soil nutrients are available to each plant. This means that there are likely to be more yellow pickles on the string plants under uniform conditions of growth. This has been commonly observed, but not proved by tests under controlled conditions.

Relation of Parasitic Diseases to Yellow Pickle

As was stated in the introduction, yellow or white pickle resembles symptoms of mosaic. It is also common to find yellow pickles associated with diseases produced by animal or plant parasites, but the yellow pickle with which we are here concerned does not come within the category of any of these diseases. When plants are affected with disease their health is impaired to the extent that they cannot mature their fruit and grow new foliage as normally growing plants can and consequently the fruit is prematurely ripened. As cucumber plants grow older, especially with the string method, they shade each other more, and for that reason the lower leaves either drop off naturally or succumb to disease. Under such conditions the plants are unable to carry to maturity the fruit which was pollinated when they were in a fairly healthy condition, and consequently many yellow pickles appear.

Soil Conditions and Yellow Pickle

Ordinarily the soil in a greenhouse is so well manured that if it is handled properly there will be sufficient soil nutrients present to carry a crop of cucumbers from nine months to a year, or as long as the vines are able to produce a paying crop. There are, however, certain conditions caused by poor drainage which tend to shorten the growing period of a plant, and materially cut down the yield. After cucumbers are transplanted, a period of soil saturation with water follows so that the plants are continually growing in a wet soil, which is usually too wet for healthy growth. If good drainage is provided, as in benches, little damage will result. If no drainage is provided, the soil becomes water-logged, oxygen is excluded and practically no nitrification takes place. The plant does not receive sufficient nitrates to make a healthy growth and a large number of yellow pickles results. Even if compost manure or fertilizer is applied on the top of the ground and kept moist, the plant will not function properly as long as the soil is in a water-logged condition. This undoubtedly has much to do with the longer growing period of cucumbers when grown in benches.

The cucumber plant needs a large quantity of water, but it will not thrive if the roots do not receive sufficient air in the presence of too much water in the soil. Greenhouse growers claim that plants wilt if the soil is not thoroughly wet down. This is true, but they will wilt even though more than the necessary amount of water is added, the reason being that the plants have received so much water from the time they were set in the beds that the root system is not large enough to balance the upper part of the plant. The roots remain near the surface and will not branch out and down for water and food. They are near the surface where there is air. It is the same condition found in a poorly drained field. If plants wilt during hot dry weather, growth is interrupted to the extent that many cucumbers become stunted and produce either nubbins or yellow pickles. Proper watering after transplanting will prevent much of this trouble. An excess of water from the time the seed germinates makes a soft plant which requires a large amount of water. It is impossible to give such a plant sufficient water during hot dry weather to prevent it from wilting, because the root system is not large enough to replace the water that is given off by the leaves. Undoubtedly, cucumbers grown with less water from the start are more lignified (less soft), have stiffer cell walls, and do not droop as readily even when there is a slight water deficit.

This condition of the soil has considerable influence on the health of the plant. The number of yellow pickles will be influenced by the condition of the plant.

THE RELATION OF DEFORMED CUCUMBERS TO CONDITIONS CAUSING YELLOW PICKLE

The cause of nubbins and deformed cucumbers is usually attributed to the fact that the flower was improperly fertilized or that the seed is degenerating. Both answers seem improbable in the light of certain observations on both healthy and diseased plants. There are plants so genetically constituted that they produce only nubbins or deformed cucumbers. But many plants later in life produce nubbins and deformed cucumbers which earlier produced number one cucumbers only. In this case we cannot attribute the condition to heredity. When nubbins are produced on greenhouse grown cucumber plants that are as freely visited by bees as plants producing number one cucumbers, we hesitate to attribute the result to a lack of pollination. It would be supposed that hand pollination should overcome the trouble, but experience has shown that resorting to such a method is no assurance that the cucumbers will be normally formed. Therefore we are led to think that the physiological balance of the plant is upset to the extent that fertilization is abnormal. This assumption, however, cannot be proven at the present time. When a plant is weak and an insufficient supply of food is available to nourish the newly pollinated flowers, the time when any given flower is pollinated may have some influence on the shape of the fruit developing from it. The number of growing cucumbers on a plant is undoubtedly a contributing cause of the production of nubbins and deformed cucumbers. By observation it has been noted that the condition of the fruit indicates the conditions under which it was produced. That is to say, if a plant is in good health and sets six cucumbers on six succeeding days, they may all start to grow. If something tends to cut down the food supply, four of the cucumbers, depending on time of pollination and position on the plant, may continue to grow uninterruptedly, while the other two stop growing until more food material is available. If two of the four cucumbers are picked the remaining two may resume growth. However, the plant is producing new foliage and new flower buds while cucumbers are maturing. If no new pistillate flowers have been formed, the two small cucumbers may grow and form cucumbers, the upper half of which will be small, while the tip half will be quite bulgy and will contain a large number of viable seeds.[1] However, if new pistillate flowers have been pollinated on the plant, they may receive the support of the plant and grow while the two small cucumbers either ripen into nubbins with a few viable seeds or become yellow pickles. This condition applies only to plants which under normal conditions produce cucumbers of good shape.

THE APPLICATION TO PRACTICE

Growers ask as to what can be done to avoid yellow pickle. The better control is, obviously, prevention. When all the yellow pickles and mature cucumbers are removed the plants put forth new growth and develop pistillate flowers, providing abundant supply of required nutrients and foods manufactured by the leaves is available. If the plants are kept healthy and vigorous at all times they will carry more pistillate flowers to maturity. Growth must be continuous and rapid. The presence of a number of maturing fruits suppresses many of the newly pollinated pistillate flowers and causes their fruit to become yellow when there are insufficient nutrients or food materials to allow rapid development of fruits present. Uniform night temperatures with moderate watering and an occasional light application of a nitrogen fertilizer to keep the plants growing, reduces yellow pickle to a minimum.

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[1] The seeds from a number of self-fertilized cucumbers of this shape have produced plants which bore perfect normally shaped cucumbers.

All cucumber houses should be well drained to prevent the soil from becoming water-logged. The young plants should be lightly watered to make them send out a good root system. The soil should be watered in such a way that the water will not stand on top of the ground. A sprinkler system is better than a hose without a nozzle, because not so much water is applied and it soaks into the soil better. The plants should be watered when it is necessary. They should not be watered as a matter of daily routine. The objective should be to get a good vigorous, healthy, fast-growing plant that will mature a large number of fertilized flowers.

Nubbins and deformed cucumbers should be removed from the vine as soon as it is apparent that they will not be well shaped cucumbers, since if once deformed they can never develop into a salable form. If they are left on the vine in the hope that they will develop into good cucumbers, they merely drain the strength of the plant and prevent it from developing normal fruit. Much less vitality is needed to produce a normal cucumber of salable size than is used to carry a nubbin to maturity, since in the former the seeds are small and undeveloped while in the latter the fruit ripens and seeds are fully developed. The removal of a maturing cucumber results in further production of pistillate flowers, and consequently further fruit production. It is a slight task to remove the nubbins when the vines are being trained or pruned.

Pruning should be a daily rather than a monthly practice. Much less damage is done if the growing tips of branches are pinched off than if seven or eight nodes are allowed to form on the branches and are then cut off with a knife. A large amount of sugar is made by the leaves of these branches and if they are cut off suddenly a starvation effect is brought about, the physiological balance of the plant is upset, and a large number of nubbins or yellow pickles will be produced.

Publication of this Document
approved by the
Commission on Administration and Finance
4,000 3-'26 Order 4442

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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 226 JANUARY, 1926

RESEARCH SERVICE
TO THE
MASSACHUSETTS APPLE INDUSTRY

PROGRESS REPORTS

This bulletin contains ten papers summarizing the more practical aspects of some of the experimental work of the Station that is of interest to fruit growers. More complete reports of some of this work may appear later in separate publications. The subjects reported upon are as follows:

The Apple Situation.......Lorian P. Jefferson and Hubert W. Yount
The Value for Massachusetts of Some of the Newer Varieties of Apples .... J. K. Shaw
Diseases of Fruit in Massachusetts in 1925 .... William Doran
Orchard Insect Pests of 1925 .... A. I. Bourne ✓
Pruning Young Apple Trees .... J. K. Shaw
Effect of Stock on Scion .... J. S. Bailey
Progress of Nursery Tree Inspection .... J. K. Shaw
The Codling Moth in Massachusetts .... A. I. Bourne ✓
Tests of Lime-Sulfur Solution and Some of Its Substitutes against San José Scale....... A. I. Bourne ✓
Some Results from Spraying with Scalecide .... A. I. Bourne ✓

Requests for Bulletins should be addressed to the
AGRICULTURAL EXPERIMENT STATION,
AMHERST, MASS.

THE APPLE SITUATION

BY LORIAN P. JEFFERSON AND HUBERT W. YOUNT

During the summer of 1925 a study of the Massachusetts apple industry was conducted as a part of an all New England study under the auspices of the agricultural experiment stations. The purposes were to discover the numbers and varieties of non-bearing and bearing trees by ages; to learn certain facts with regard to orchards and orchard practice; to determine the quantities and grades sold of each variety, and the methods of sale and the prices received.

The data were collected through personal visits to commercial orchard owners throughout the state. A tentative minimum of 100 bearing trees was fixed as determining a commercial orchard, but smaller orchards were considered if evidently of commercial importance. Approximately 1750 growers were visited, complete information on both trees and production being secured from about 1700.

The results of the study can not be fully stated here, but the following facts and figures give a summary of the situation as shown by the survey, so far as number of trees and plantings are concerned. It should be borne in mind that these figures relate only to orchards of commercial importance and do not include the trees in thousands of small farm orchards.

The owners of the orchards visited reported a total of 967,000 trees, over 600,000 of which were in bearing. More than seventy-five varieties were reported, but the principal ones together with the number of trees in each table are shown in Table 1. The Baldwin is by far the most important variety, having 45 per cent of the bearing trees and over 50 per cent of the commercial crop.

The McIntosh ranks second with 117,000 bearing trees or 20 per cent of the total, and 13 per cent of the apples grown. Nearly 85 per cent of the bearing McIntosh are under fifteen years of age, which accounts for the relatively low yield. In view of this fact and the large number of trees not yet bearing, the production of McIntosh apples may reasonably be expected to increase 100 per cent within the next ten years. Only 28 per cent of bearing Baldwin trees are under fifteen years of age, but there will probably be an increase of about 20 per cent in Baldwin production within the next decade. The early varieties such as the Transparent and Duchess are relatively unimportant both as to number of trees and production. Only about 5 per cent of all bearing trees fall within this class.

The Wealthy is third in importance so far as bearing trees are concerned, but the Gravenstein, with nearly the same number of trees, produces almost twice the crop. Coupled with the fact that many Wealthy trees are fillers, this gives the Gravenstein third place as a commercial variety.

New Plantings

The past ten years have been years of very heavy plantings, over 460,000 trees being set during this period. The plantings of Baldwins and McIntosh have been about equal. Since 1920, however, there has been a decrease in the rate of planting. From 1914 to 1919 approximately 95,000 McIntosh and 70,000 Baldwin trees were planted. During the period since 1920, there have been only 61,000 McIntosh and 55,000 Baldwins planted, a relative decline in planting, for the five-year period, of 35 per cent for the McIntosh and 20 per cent for the Baldwins. Plantings of all varieties have declined 20 per cent in the same period.

Of the winter varieties, the Delicious shows the greatest percentual increase in plantings, some 36,000 trees of this variety having been set in the last ten years, practically all being permanent. Other winter varieties have been planted in considerable numbers, the Wagener being a favorite. The older varieties, such as Greening, Spy and Russet, are rapidly disappearing, few new plantings being reported.

FILLERS

The Wealthy is the variety most commonly planted as fillers. Out of a total of 34,000 bearing Wealthy trees, 15,000 were reported as fillers to be cut within the next five to eight years. In the younger plantings over two-thirds of the Wealthy are fillers. Relatively few McIntosh have been set as fillers, and where this was done some years ago, growers are cutting out the permanents and leaving the McIntosh. Wagener is also popular as a filler, nearly all the Wageners planted being used for that purpose. Duchess and Transparent have also been used in some quantities, about one-third of the bearing trees of these varieties being fillers.

TABLE 1. Number of Bearing and Non-Bearing Trees of Leading Varieties, 1925.

Variety	Non-Bearing			Bearing		
	Perm'ent	Filler	Total	Perm'ent	Filler	Total
Summer Varieties:						
Transparent....	5,095	1,648	6,743	6,673	2,811	9,484
Astrachan......	5,458	631	6,089	7,003	398	7,401
Williams.......	2,141	108	2,249	4,567	590	5,157
Duchess.......	5,148	3,898	9,046	7,149	3,836	10,985
Other.........	971	79	1,050	1,795	64	1,859
Total........	18,813	6,364	25,177	27,187	7,699	34,886
Fall Varieties:						
Gravenstein....	20,447	392	20,839	28,525	60	28,585
Wealthy.......	11,356	18,059	29,415	19,987	15,147	35,134
McIntosh......	111,656	5,188	116,844	112,980	4,432	117,412
Other.........	7,381	481	7,862	15,029	2,643	17,672
Total........	150,840	24,120	174,960	176,521	22,282	198,803
Winter Varieties:						
Baldwin......	108,085	200	108,285	277,338	1,228	278,566
Spy.........	3,161	5	3,166	7,608	145	7,753
Delicious.....	31,457	1,228	32,685	9,325	45	9,370
Greening......	2,116	....	2,116	11,304	242	11,546
Other.........	18,773	1,391	20,164	67,844	2,181	70,025
Total......	163,592	2,824	166,416	373,419	3,841	377,260
Grand Total.....	333,245	33,308	366,553	577,127	33,822	610,949

TABLE 2. Number of Trees by Age Group, 1925

Age—Years	Perm'ent	Filler	Total
Non-Bearing:			
Under 5	180,482	21,545	202,027
5–9	150,470	11,763	162,233
Old	2,293	....	2,293
Total	333,245	33,308	366,553
Bearing:			
Under 10	85,883	11,256	97,139
10–14	164,993	19,997	184,990
15–19	60,351	2,114	62,465
20–29	55,991	391	56,382
30 or over	133,133	15	133,148
Unclassified	76,776	49	76,825
Total	577,127	33,822	610,949

TABLE 3. Number and Age of Trees in Summer, Fall and Winter Variety Groups.

Age—Years	Summer	Fall	Winter	Total
Non-Bearing:				
Under 5	15,141	93,490	93,396	202,027
5–9	9,987	81,363	70,883	162,233
Old	49	107	2,137	2,293
Total	25,177	174,960	166,416	366,553
Bearing:				
Under 10	9,602	55,970	31,567	97,139
10–14	13,215	89,206	82,569	184,990
15–19	3,964	20,448	38,053	62,465
20–29	2,433	11,306	42,643	56,382
30 or over	3,658	9,023	120,467	133,148
Unclassified	2,014	12,850	61,961	76,825
Total	34,886	198,803	377,260	610,949

THE VALUE FOR MASSACHUSETTS OF SOME OF THE NEWER VARIETIES OF APPLES

BY J. K. SHAW

The question of the best varieties of apples for planting will never be settled. While it is true that we have too many varieties and that nearly every fruit grower has in his orchard varieties that never should have been planted, yet no variety is perfect and the alert grower is constantly on the watch for something better. Then too, conditions are constantly changing and a variety that is quite satisfactory now may not meet the demands of the situation a few years hence. The man who anticipates the opportunity of a new variety and plants it early will receive the largest rewards; but on the other hand one who plants largely of a new variety that does not fulfill its early promise may suffer material losses. The choice of varieties is a most important question, for mistakes are not easily corrected.

Several varieties are now on trial in Massachusetts, and the following comments based on observations in the Experiment Station orchards and on the experience of others in this and other states is offered for the information of orchardists.

CORTLAND

The Cortland is a cross of Ben Davis and McIntosh originated at the New York Experiment Station. It has been considerably planted in New York where it seems to be meeting increasing favor. The supply of nursery trees has been limited, but nurserymen are now propagating them in greatly increasing numbers and liberal supplies of yearling trees are now available. More than 35,000 trees of this variety were certified by the Massachusetts Fruit Growers' Association in 1925.

Cortland is naturally compared with its parent McIntosh. Our experience indicates that in Massachusetts it will hang to the tree much better than McIntosh and need not be picked until at least two weeks later. It matures in storage later and will keep from one to two months longer. It stands handling distinctly better. Its susceptibility to Scab is no greater and may be a little less. The hardiness, vigor and growth habit of the tree are very satisfactory. It comes in bearing early and bears annually while young, and the fact that both parents tend to be annual bearers encourages the belief that it will keep up this habit very well with age.

It has the same white tender flesh as the McIntosh but is distinctly inferior in flavor. It lacks the spicy richness of its parent variety. It is, however, a good apple, probably equal and possibly superior to Baldwin. In appearance, while a handsome well colored apple, it is hardly equal to McIntosh and it appears to be less uniform in size and shape. Our judgment is that it will not replace McIntosh in New England though it will find a place in extending the McIntosh season.

DELICIOUS

The Delicious has enjoyed an increasing favor over wide areas as a high class dessert apple. It is worthless for cooking purposes, unless for pies, so that fruit not attractive for fruit stand trade is good only for cider or similar uses. It has been considerably planted in Massachusetts, and its behavior is variable. In the Experiment Station orchards it tends to run small and of rather poor color after a few years' bearing. It bears heavily biennially. It seems to be more generally successful in Norfolk, Plymouth and Bristol counties than in the rest of the state. In western Massachusetts it does not do very well.

The tree is vigorous, upright spreading in habit and considerably hardier than Baldwin. It makes a rather dense head but after it reaches bearing age it is not objectionable in this way.

Probably the Delicious is more uniformly successful in other sections than it is in New England. If this is true it is doubtful if it ever attains here a place comparable with that of Baldwin and McIntosh. Possibly increased knowledge may lead to better management that will overcome its tendency to run small on mature trees. Thinning and nitrogen applications in midsummer may prove to be means to this end.

It follows that Massachusetts growers should use some caution in planting Delicious, at least until means of attaining uniformly high quality are more certainly known. No one may wisely plant it unless he is prepared to grow it skillfully so as to produce a high quality product that will meet the demand for a fancy dessert fruit. It is not a variety for a careless grower.

Golden Delicious

Much interest has been excited about the Golden Delicious, due to the extensive advertising it receives from the nursery firm introducing it. As grown in the Middle West it is a handsome waxen yellow apple of excellent quality. The tree is vigorous and begins to bear at a remarkably early age. It is apparently very productive. The apple hangs well to the tree and keeps and stands handling very well. In the humid climate of New England it does not seem to attain this clear waxen color, it is a more dull yellow and a little inclined to russet. It is doubtful if it attains the size it does where the growing season is longer.

Most of our New England markets have a distinct prejudice against yellow apples. This may be foolish, but it must be taken into consideration by fruit growers. Probably the extensive advertising this variety is receiving will go far towards overcoming this prejudice, but unless it succeeds better than preliminary observations indicate we cannot compete successfully with Golden Delicious grown in other sections where it attains greater attractiveness and possibly better quality.

Red Bud Sports

Many cases are known where a single branch on a tree normally bearing striped or splashed apples has produced fruit of a distinctly more intense red color, and this character is uniformly transmitted by buds taken from these branches. In other respects it is generally exactly like the parent variety. Many such "bud sports" of the Gravenstein have appeared in this state and elsewhere, and Rome, Twenty Ounce and other varieties show them occasionally. None of these red sports has attained very great favor with growers.

Recently a bud sport of the Delicious has been brought strongly to the attention of fruit men under the name of Starking. It is beyond doubt a true red bud sport of distinctly deeper color than Delicious usually has, yet well colored Delicious may equal Starking in color. The deeper color of the new variety ought to be an advantage and if it is equal to Delicious in all respects, as may reasonably be expected, it may largely replace the parent variety.

Another red sport is the Red Spy, a solid red variation of the Northern Spy. It is reputed to be exactly like the old variety except in color. There is a question if it is more attractive in appearance than the best of Spies, yet it is well worth a trial by the patient fruit grower who wants to grow Spy.

Many red sports of Gravenstein have appeared, not all alike. One of the most recent ones is distinctly redder than others, being equal to the best colored Williams. As eastern Massachusetts is about the only fruit growing section, outside of California, that grows Gravenstein, this red sport should appeal to our growers who desire higher colored fruit.

DISEASES OF FRUIT IN MASSACHUSETTS IN 1925

BY WILLIAM DORAN

The Department of Botany of the Massachusetts Agricultural Experiment Station receives many requests for information on the identification and control of plant diseases. On such correspondence and on farm visits by the staff, is based this estimate or composite of the occurrence and severity of fruit diseases in 1925. As is developed below, fruit diseases in general probably caused less loss than usual.

Spray Schedule and Spray Materials

In most commercial orchards in Massachusetts the spray schedule on McIntosh consists of the following applications: pre-pink, pink, calyx, first post-calyx, and (in some orchards) a second post-calyx. Baldwins and other varieties considered less susceptible to scab, are given the pink, calyx, and first post-calyx application. In the case of "off-years" when certain varieties are not bearing, the number of applications is much reduced or perhaps none is given.

The favorite material is liquid or dry lime-sulfur. A few orchardists are partial to Bordeaux mixture for the pre-blossom applications. Those who own dusters are using sulfur dust for all applications or for the calyx and post-calyx applications only, depending on the sprayer for pre-blossom applications. Wettable sulfur (such as dry-mix sulfur-lime) is preferred by a few. Calcium caseinate spreader (such as "Kayso" or "Spracein") is generally used in the lime-sulfur-lead arsenate combination.

Scab of Apple

Most orchardists are familiar with the fact that the first infection of apple scab may occur when spores are ejected from the dead leaves in which the fungus has passed the winter. In 1925, in the Nashoba area, such spores were first ejected between April 29 and May 1. In this same region, this critical date was April 26 in 1921, May 2 in 1922, May 3 in 1923 and May 3 in 1924. It is thus seen that for five successive years this date has occurred about May 1 and within a range of eight days. We would expect it to be slightly earlier in southeastern Massachusetts and somewhat later in the highlands of Worcester County and the counties to the west, exclusive of the Connecticut Valley.

Apple scab this year was on the whole of average, or perhaps slightly less than average, severity, as indicated by the condition of the fruit on unsprayed or poorly sprayed trees. Good spraying gave practically complete protection even on McIntosh and other susceptible varieties. West of the Connecticut Valley there was a light infection on Baldwins. In the Connecticut Valley, the disease became conspicuous later than usual and in some orchards was regarded as severe on McIntosh and Delicious. There was evidence that the second post-calyx application on McIntosh gave some increased protection. In eastern Massachusetts some orchardists had as much scab on Baldwins as on McIntosh, or more. This was, perhaps, due to the fact that in many orchards the Baldwin received only one pre-blossom application while the McIntosh had two, and to the fact that many of the Baldwins are old and tall trees and consequently more difficult to spray well. In most orchards scab became conspicuous on the fruit in July and continued to increase until into September.

SPRAY INJURY .

The occurrence of spray injury is affected by the materials used, the manner of application, the susceptibility of varieties, and the weather at the time of and following the application. This being the case, it is not surprising to find that there was serious spray injury this year in some orchards and none at all in others.

In some orchards there was considerable spray injury on the fruit of Baldwin. But the most severe injury was on McIntosh, fruit russeting proceeding so far as to cause the fruit to crack. Leaf injury, in the form of curling, yellowing, or burning of leaf margins was in some cases associated with fruit russeting. This was easily confused with a condition which occurred on the leaves of certain young and unsprayed trees where the leaves showed a brown or blackened margin, probably caused by the high temperatures and drying winds to which these leaves were subjected during their period of development before the tissues hardened.

Spray injury as it occurred this year has been ascribed to the use of the spray gun, to the high temperatures which prevailed during the spraying season, to the use of fungicides containing copper, and to arsenical injury. The worst spray injury brought to our attention occurred in orchards which received pre-blossom applications of Bordeaux mixture or copper dust, with sulfur fungicides used for the calyx and post-calyx applications. Evidence was secured in 1924 that even for pre-blossom applications copper fungicides are less safe than are sulfur fungicides. As recorded by the present writer in Massachusetts Agricultural Experiment Station Bulletin No. 222, there was an average of 14 per cent russeted McIntosh apples on plots which received pre-blossom applications of Bordeaux mixture, and less than 1 per cent on plots which received pre-blossom applications of lime-sulfur. This year, there was of course some spray injury in certain orchards where only sulfur fungicides were used. Some of this may have been due to the use of a spray gun close to the trees and to the unusually high temperatures during the spraying season. During the first ten days of June the temperature was very high, with the maximum above 90° F. for four days in the eastern half of the state. In their study of foliage injury by arsenical sprays, Fernald and Bourne found (Mass. Agr. Exp. Sta. Bul. No. 207) that it is not safe to spray the apple when the temperature is 90° F. and the relative humidity above 67 per cent. It is therefore reasonable to ascribe some of the injury this year to arsenical burning, for this temperature and humidity combination was reached or exceeded during the spraying period in early June.

Black Rot

Black rot of the fruit of the apple was not generally serious this year, although certain individual growers considered it more serious than in 1924. It was reported on Baldwin, Greening, and Yellow Transparent, and was most common on Baldwin. Black rot was not serious even on fruit which showed severe spray injury. This is of interest since in some seasons black rot has been associated with or has followed blossom-end injury due to the calyx spray.

Black rot canker is the most common of the limb cankers, but in most commercial orchards it is not serious. It is often present on old Baldwins, and failure to spray and prune such trees properly results in its rapid increase in severity. Occasionally this disease causes serious loss in young and apparently well cared-for orchards, but such a condition is exceptional in this state.

Cedar Rust of Apple

This disease was practically absent or existed only in traces (and then on Wealthy) in the Nashoba district. Most orchardists have seen to it that red cedars were removed. There was light infection on Wealthy and Banana in western Massachusetts. The sporidia or spores by which this fungus passes from cedar to apple require water for their dissemination, and during that period in spring when this ordinarily occurs the rainfall was deficient.

Sooty-mold and Fly Speck

This disease was of no great importance this year. It was observed in a few instances on Baldwins and Greenings. It occurred more or less throughout the state, but, except on unsprayed and unpruned trees, it was of no consequence. Ordinarily there is more of this disease in the eastern than in the western part of Massachusetts. It may often be seen on drop apples which have remained long on the ground even when not evident on the fruit on the tree.

Baldwin-Spot

This disease, which also goes under the names of stippen or bitter-pit, is well known to orchardists. Unfortunately its cause and control are obscure.

Baldwin-spot was of somewhat more than average severity this year. In many orchards this was the "off-year" for Baldwins, and the disease was generally associated with a light crop and consequently larger fruit. It was not conspicuous in orchards where the fruit was smaller. The occurrence of the disease has an evident relation to alternate bearing and to thinning. Baldwin-spot may occur on other varieties, but this year it was called to our attention only on Baldwin and Stark.

Fire Blight of Apple and Pear

In eastern Massachusetts fire blight occurred about as usual in most orchards, although from a few orchards there were reports of its being on the increase, especially on Gravenstein and Wagener. In well cared-for orchards the removal of the more susceptible hosts has helped to reduce the menace of this disease.

In western Massachusetts, where the disease on the whole was not of great importance, it was present in a few Baldwin and young Wealthy orchards. In a few orchards in the Connecticut Valley it was serious, much more so than in the orchards of eastern Massachusetts with which we are familiar.

Fire blight on pear occurred throughout the state in varying degrees of severity, from serious in some orchards to none at all in others. It was more general on odd or unimportant varieties than on the standard or commercial varieties. It was observed that unnecessary pruning of healthy trees is likely to be followed by an increase in fire blight.

Other Diseases of Pear

Pear scab was severe in some unsprayed orchards, and if the pear increases in commercial importance here, more attention will need to be given to protection against this disease.

Black rot was reported in a few cases on Bosc pears.

Diseases of Peach

Leaf-curl of the peach was not as bad as usual this year. The ordinary dormant spray of lime-sulfur gave practically complete control, but in certain orchards where this application was not given, the disease was severe.

Brown rot of peach (and plum) was generally present although varying in severity in different orchards. In general, severe orchard infection was not apparent, and the ordinary use of sulfur fungicides, either sprays or dusts, gave a good control. But rotting of the fruit in the market due to this disease was often very bad. Brown rot was more severe on early than on late varieties of peaches. In some cases it was very severe on plums.

Miscellaneous Diseases

Downy mildew of grape was more than usually common. If grapes increase in commercial importance in this state, this disease will be one of the principal enemies of the crop. Fortunately, control by copper fungicides is not ordinarily difficult.

Mosaic of raspberry is of general occurrence. Its effects are becoming more conspicuous each year. The most practical action to take against it consists in the purchase of plants known to be free from the disease.

A root-rot of strawberries was rather common on second-year beds in early summer. Various soil fungi were found associated with it, but it is believed that they were only weakly parasitic and that the primary cause was connected with lack of soil moisture.

ORCHARD INSECT PESTS OF 1925

BY A. I. BOURNE

Perhaps the outstanding feature of the first part of the season was the early transition from winter to spring conditions. This was so marked that at the close of March it was estimated we stood fully two weeks in advance of the normal seasonal development. Although this progress was somewhat slowed up by unfavorable weather conditions encountered in April and May, yet this initial advance was not wholly lost throughout the rest of the season. Sensitive as we have found insects to be to varying weather conditions, it was but natural that we should expect them to commence their activities at a correspondingly earlier date. This is what actually happened.

Orchard Plant Lice began hatching during the last week of March, the earliest record since 1921. Reports from all parts of the state showed them present in unusual abundance. In some orchards they were out so early that the dormant oil sprays nearly wiped them out. They remained very abundant until the long-drawn-out period of cold, unfavorable weather the latter part of April, after which they practically disappeared from the orchards. Many growers found so few plant lice that they omitted the nicotine from the pink and calyx sprays. There were occasional small local outbreaks reported late in the season. These were confined chiefly to young trees, and even then were not a serious factor.

Leafhoppers, so prevalent in 1924, were practically absent from orchards this season. In many cases, where a year ago it was possible to find thirty or more young hoppers on a leaf, this season it was almost impossible to find any. In some orchards where for years they have been considered to be one of the worst pests, they were almost entirely absent this season.

One pest which was still rampant, and offers as yet no sign of relief, was the Apple Tent Caterpillar. From all parts of the state, it was reported as at least as abundant as last year. It is certainly true that, from Worcester County west, this insect is still on the increase. While it was in great abundance on roadside trees and on uncared-for apples in pastures, it also had worked into the orchards, and its control often became a real factor to be considered. Careful attention to this pest in the pink spray was found to control it.

The European Red Mite, in the early part of the season, did not appear to be very abundant. The widespread use of oils the previous spring had apparently so reduced it in numbers that many growers did not give it special attention. During the late summer, in the eastern part of the state especially, a rather heavy infestation developed, which increased rapidly so that. by the middle to last of August and into September, considerable bronzing of foliage resulted. This appeared to some extent in other parts of the state, especially where oil sprays had been omitted in the spring. Some growers expressed the opinion that this heavy attack ot mites, late in the season, caused an early dropping of fruit.

No reports of any serious abundance of Red Bugs were received, nor did personal visits to the orchards bring to light any cases of severe injury. Apparently, over the state as a whole, it was either considerably below normal in abundance, or else so well controlled by the spray program followed that it was checked almost at the outset.

The Round-headed Apple-tree Borer continued to be a very serious factor especially in some of the orchards in the western part of the state, although found to be present to some extent in orchards in other sections. This insect does not appear to fluctuate as do many of our pests, but holds very regular in abundance year after year. When it offers any real problem, careful and repeated "worming" of the trees over a period of years enables the grower to gradually bring it under control, or at least materially reduce its abundance.

The Apple and Thorn Skeletonizer in its first two broods proved to be slightly less abundant than usual. It has been our experience, in Massachusetts, that the worst trouble has come from the larvae of the brood maturing the last of July and early in August. This season, this brood was much smaller than usual, and little or no injury was noted. The generation of larvae which came to maturity in early September proved, however, to be unusually large, and a considerable amount of late skeletonizing resulted all over the state. Coming so late in the season, this caused very little concern, and few, if any, of the growers deemed control measures to be necessary.

Over the state as a whole, the San José scale appeared to cause little damage. For the last few years, however, complaints of an increasing local abundance have come in from many points in the state. In some orchards it has developed into a real problem for the grower to face. The rapid spread of the Red Mite and consequent increased use of oil sprays in the dormant season have very often automatically solved the problem of the control of this scale. When, as frequently happens, a grower finds scale in any amount on his harvested fruit, he should use prompt measures for control in his orchard. Oyster-shell Scale is very generally present in practically all of our orchards, but seldom, if ever, is found in destructive abundance.

Early indications, borne out as the season developed, were that the Gypsy and Brown Tail Moths, if present at all in the orchards, were in such small numbers that they constituted no real problem for the growers Treatment of the overwintering egg masses of the Gypsy Moth was practically the only real control measure required.

This year the Plum Curculio began to appear in the orchards very close to the time of the calyx application. This was some two weeks earlier than it appeared in 1924. From the first it gave every indication of even greater abundance than in 1924. While in the best cared-for orchards its injury was held within moderate bounds, this insect still stands as one of the most serious of our orchard pests. It occurs with such regularity, year after year, that unless unusually hard hit, the grower has come to take it for granted, and therefore it is difficult to estimate accurately its relative abundance. It is, without any question, everywhere a serious pest; causes a large annual loss to the growers; and as yet is still far beyond successful control.

The Codling Moth was more abundant than usual over the state as a whole. Through the large fruit growing section in the eastern part of the state, it was often reported to have been the worst pest of the season. There was a considerable amount of early "side worm" injury from late hatching larvae of the first brood. In late summer, there was a very general and unusual amount of damage from second brood larvae. A study of the spray program followed by many of the growers showed very clearly that, where the calyx spray is carefully applied, growers are able to eliminate "blossom end" injury almost completely. Where one or two post-calyx applications have been made to cover fruit and foliage at the time the young larvae are hatching and infestation of the fruit taking place, it has been found possible to secure a very large measure of control. This past season an unusually large second brood developed, which caused much late "side worm" trouble. This was undoubtedly due to a very great extent to the fact that the first brood larvae matured and began leaving the fruit to spin cocoons, earlier than usual. Consequently a larger percentage pupated and formed second brood moths. It should be noted that growers who made one or two post-calyx applications of spray or dust, and followed these with an application early in August, suffered very slight loss from "side worms," either early or late. It is increasingly evident that, for the control of this pest, attention to the post-calyx applications is as necessary as to the calyx spray itself.

In late summer there appeared in all parts of the state an unusually heavy attack of the Apple Maggot or Railroad Worm. Others of the northern fruit growing states encountered a similar outbreak. The attack was somewhat uneven in its intensity, although no particular region of the state entirely escaped. It developed to serious proportions rather late in the summer, and, of the chief commercial varieties, the Wealthy appeared to suffer the worst, while McIntosh and even Baldwin in some cases were severely attacked, and one case of severe injury to Ben Davis was reported. This outbreak appeared so suddenly that many growers were unaware of its serious nature until the fruit began to be harvested and moved into the market; one result of which was that the market became rather suspicious, particularly of Wealthies. Whether this insect will be present in such numbers another season, it is impossible at this time to forecast. Growers should keep a sharp lookout in their orchards next season for the appearance of the adults, to determine the danger of attack. Careful disposal of cull fruit after a season of such unusual abundance is particularly stressed, to offer the least opportunity for the concentration of maggots in or near orchards.

The season was not marked by any serious outbreak of what may be classed as lesser fruit pests. Pear Psylla was present to the usual extent, but rarely in serious numbers. The Peach Tree Borer, largely because of the success of the Paradichlorobenzine treatment, has been reduced to a pest of but secondary importance. Fall Webworm was present in about normal abundance. When the fruit came to be harvested and graded, there was found to be an unusual amount of late injury by the Lesser Apple Worm and Red-banded Leaf Roller. This was noticeable on Baldwins especially.

The season was marked, however, by local outbreaks of some insects not usually found in abundance.

Early in the season, from several points in northwestern Worcester County, Climbing Cutworms were found to have been unusually abundant. On young trees especially, their injury was often severe. Young opening buds were devoured by these larvae, which from their habit of feeding at night and hiding by day gave no inkling of their presence until much of their damage was done. Many small, recently set trees were completely denuded of buds; others, not so severely attacked, lost such a proportion of buds that they were able to make but a feeble start, and were checked more or less through the season. Less severely injured trees were usually able to overcome this early setback and make a fairly normal growth. In some cases, not only were the buds completely devoured, but the hungry cutworms gnawed the tender bark just around them, clear in to the wood.

Somewhat later in the season, a few cases were noted of Click Beetles also gouging into buds and opening flowers. This injury, too, was most noticeable on young trees, but in no case as severe as that noted above, caused by Cutworms. .

Early in June, reports of an outbreak of Pear Midge were received from points in Plymouth and Barnstable counties. As far as could be learned, this was not general, but was confined to local outbreaks in that region. Where the pest was reported, however, it was found to be causing severe damage. In some cases, over 50 per cent of the crop was estimated to have been attacked. Clapp's Favorite and Beurre Bosc were the two varieties specifically mentioned as being the most severely infested.

During late September and early October, there was discovered some injury to fruit caused by the so-called Dock False Worm. In one orchard, at least, larvae of this Sawfly were found to have bored into the fruit in considerable numbers. This was noted especially on Baldwins. Through the summer this insect feeds mainly on species of dock, sorrel, etc., and attacks fruit only in the fall when it seeks quarters for hibernation. The larvae bore into the fruit, making small round holes which soon show a slightly sunken, discolored ring on the surface of the apple. Inside the fruit these burrows run well toward the core, usually enlarged slightly toward the inner end where the small, light green larvae may be found. These entrance holes in the apples, while somewhat larger than those made by the Codling Moth, are probably often mistaken for those of that insect. As this insect is primarily a pest on different varieties of weeds, clean culture is obviously the best protection against it. In all probability this insect will seldom, if ever, become a serious pest in orchards. It is well for the grower, however, to be aware of its presence.

Taking the season as a whole, without any question the fruit growers' main troubles were caused by mid-season and late Codling Moth injury, the Plum Curculio and the Railroad Worm. Some of the pests commonly found in abundance were this season practically absent. On the other hand, one or two species, not usually found in numbers enough to warrant any attention from the growers, were encountered in considerable local abundance.

A survey of insect conditions made in the main fruit growing section of the state brought out very clearly the emphasis which should be given to careful and properly timed spraying. In spite of the diversity of insect attack which fruit growers encountered, it is significant that those who gave closest attention to spray or dust applications reported their orchards and fruit remarkably free from injury by insects. This was most noticeably true of those who gave particular attention to the post-calyx and mid-season applications.

PRUNING YOUNG APPLE TREES

BY J. K. SHAW

In the spring of 1916 an orchard of 600 one-year-old trees of Baldwin, Northern Spy, Rhode Island Greening, McIntosh and King were set ten feet apart, for an experiment in pruning with especial reference to head formation. Six different methods of pruning were arbitrarily chosen and consistently followed for a period of nine years. It is the purpose of this paper to present some of the conclusions reached from this experiment, that may be of value to the fruit grower. A more detailed report of the technical aspects of the experiment is in preparation.

The pruning methods chosen were as follows:—

1. The whips to be cut back at planting and the new growth cut back about one-half, the cutting back to be less severe in succeeding years. They were to be thinned out each year the same as the other types of pruning. The purpose was to produce a globular shaped tree, headed back annually.

2. Trees to be cut back at planting as in 1, and to be thinned out the same but not headed back. The purpose was to produce a globular headed tree not cut back.

3. The trees to grow without any pruning whatever except the removal of suckers and water sprouts.

4. The trees to be set without cutting back and the leader allowed to grow to a height of 7 to 8 feet and then suppressed if necessary. They were to be thinned out annually the same as the other types of pruning. The purpose was to produce a modified leader tree.

5. The trees to be set without cutting back, but to have all shoots except the leader headed back in later years, but a little less severely than the cut-back globular trees. The purpose was to produce a central leader tree.

6. The trees to be pruned as in 5, but without cutting back. The purpose was to produce a central leader tree without cutting back.

All trees except the unpruned were to be thinned out to about the same density, and two of the lots were to have the new growth cut back each year.

These five types of pruning were expected to produce, more or less successfully, three types of trees:—the globular headed tree generally preferred in Massachusetts, the modified leader type, and the central leader type. In 1922 when the type of tree was pretty well fixed, an estimate of the degree of success reached in securing these types was made, and the results are shown in Table 1.

Table 1. Degree of success in attaining the expected type of tree.

(Number of trees)

	Failure	Rather Unsuccessful	Fairly Successful	Successful	Highly Successful
Globular cut back....	0	0	5	26	68
Globular not cut back.	0	0	6	29	64
Modified leader.......	0	4	17	32	45
Central leader cut back	16	14	19	19	29
Central leader not cut back	24	23	26	17	10

This classification is, of course, wholly arbitrary and another observer might have classified them somewhat differently. Certain generalizations may, however, be quite safely made. It is evident that the globular headed tree may be more certainly secured than the central leader type and that cutting back the branches helps to produce a leader tree. The trees classed as failures were well formed trees and not by any means failures as orchard trees, but they did not have in any degree a dominant central leader. There was some difference in the five varieties used. Spy and McIntosh were rather more tractable than the other varieties, partly owing to winter-killing in the severe winter of 1917-18 which injured many Baldwins and Rhode Island Greenings and a few Kings. Several trees among the Baldwins, Spies and Kings were killed back to the snow line or severely checked by killing the wood while the bark and outer thin shell of wood remained alive. This doubtless interfered with the rise of water and checked growth for a year or two. Where they were killed back to the snow line a strong shoot arose in many cases and a good leader tree resulted.

The unpruned trees generally assumed a modified leader type and have naturally developed rather thick tops with many branches coming out of the central trunk.

Cutting back young trees is generally advocated, one object being to secure low headed trees. In 1919 measurements were made of the height of the lowest branches on these trees. The maximum difference between the average of trees cut back at planting and those not cut back was only about seven inches, a difference that is of no significance in mature trees.

An argument for cutting back frequently advanced is that it makes the tree, including the cut back branches, more stocky. It is now generally recognized that any increase in stockiness arises from shortening the branch and not from increased diameter. In the fall of 1923 the four largest branches on each tree of the Baldwins, Rhode Island Greenings and McIntosh trees were measured four inches from the trunk. The relative size of these branches is shown in Table 2, the unpruned trees being taken as 100.

TABLE 2. Relative size of branches of trees receiving different types of pruning.

	Baldwin	Rhode Isl'd Greening	McIntosh	Average
Unpruned	100	100	100	100
Globular cut back	121	123	139	128
Globular not cut back	144	131	139	138
Modified leader	114	103	118	112
Leader cut back	114	91	108	104
Leader not cut back	128	126	113	122

It will be seen that cutting back the side branches has not increased their diameter; but on the contrary, in all except the McIntosh, they are smaller on the cut back trees. The principal factor governing the size of the main branches is their number. The fewer branches there are the larger the four principal branches may grow; that is why all the pruned trees (except the cut back leader Rhode Island Greening) have larger main branches than the unpruned trees. It also explains why the four largest branches on the globular trees are larger than those on the leader trees; there are fewer additional smaller branches to compete.

After the growing season of 1924, when the trees had completed nine seasons growth, the height and spread of the trees were measured, and the average of all varieties for the several methods of pruning is shown in Table 3.

Table 3. Average size of trees at nine years old (feet).

	Height	Spread
Globular cut back	15.0	11.8
Globular not cut back	16.1	14.8
Unpruned	16.7	14.7
Modified leader	16.7	15.1
Leader cut back	17.0	12.4
Leader not cut back	16.9	15.5

This table shows that the leader trees are only a little taller than the globular trees. It is perhaps true that there will be more difference when the trees come in bearing, for the scaffold limbs of the globular headed trees may bend down with loads of fruit.

Cutting back the globular headed trees has made them a little shorter and both these and the cut back leader trees have less spread than the trees not cut back. It is now generally considered that pruning dwarfs trees, but these figures indicate that the rather light pruning practiced here has not dwarfed the trees much except where cutting back was practiced. Thinning out the top leaves the remaining foliage better exposed to the light and this may compensate for the reduction in leaf area from pruning.

The practice of cutting back new shoots annually on young trees was formerly quite generally advocated for young trees. Our experience with this orchard would lead us to avoid cutting back except where it is desired to dwarf one or more branches so that they will not outgrow other parts of the tree.

Bloom and Yield

This orchard has not produced much fruit. None has been borne by the Northern Spy trees, and product of the Kings is negligible. The first crop of the other varieties was in 1922 and there has been a light to moderate crop each year since. The McIntosh trees have naturally borne the most, averaging over 4½ bushels per tree for the four years total crop. The average percentage of bloom and the total yield per tree is shown in Table 4. The most significant fact brought out is the effect of annual cutting back. It has decreased bloom in every case and decreased yield in all cases except the globular McIntosh. Probably the differences between the different types of pruning, not involving cutting back, and including the unpruned trees, are of no great significance. While the tops of the unpruned trees are pretty thick, no marked inferiority of the fruit in either size, color or quality has yet appeared.

The one-year whips set without cutting back made a very poor growth the first season. Most of them sent out two or three side branches not over a foot long. The second year these trees sent out additional branches, and, had it not been for the limitation imposed by the plan of the experiment, might all have been developed into strong well formed trees. Indeed, they are more satisfactory than are many commercial orchards.

TABLE 4. Bloom and yield, 1922-25 inclusive.

	Average percentage of bloom			Total yield, pounds per tree			
	Baldwin	R. I. Greening	McIntosh	Baldwin	R. I. Greening	McIntosh	Total, all varieties
Unpruned	4	13	29	48	55	197	300
Globular cut back	1	10	13	17	34	160	211
Globular not cut back	2	17	21	42	51	141	234
Modified leader	4	18	31	41	52	256	349
Leader cut back	1	16	18	9	32	140	181
Leader not cut back	2	24	28	32	34	223	289

The trees cut back at setting sent out three or four strong shoots. Generally one of these might have been developed as a leader had the plan of the experiment allowed. It is felt that a one-year tree may be cut back at planting or not as the planter desires, but if cut back at setting one shoot should be chosen and maintained as a leader for a few following years. In order to do this the other branches will require cutting back. If it is not cut back, growing conditions must be favorable and one should not be discouraged if rather poor growth is made the first season; it may be expected to be as large as, or larger than a cut back tree after two or three years.

During the three or four years while the leader is developing, several permanent scaffold branches should be selected. These may well be a foot apart even if on opposite sides of the trunk, for if too close they will check the growth of the leader. Not more than two or three satisfactory candidates for main scaffold branches can be expected during the first season of growth.

These scaffold branches should not be cut back except as necessary to keep them about the same size. To insure this equality will require some pruning, especially of the older, lower branches. Cutting back will be more effective than thinning out where it is desired to hold back a branch. It will be generally understood that these main branches should be well distributed around the tree as well as along the leader, in order to produce a tree equally developed on all sides.

The remaining branches not desired for permanent scaffold limbs may be cut out where they are too plentiful or cut back if necessary to keep them smaller than the permanent branches. They may then contribute to the growth of the tree and some of them may serve for a few years as fruiting branches, being removed when the growth from the permanent scaffold branches weakens them by stronger growth and consequent shading.

It is probably safe to urge that as little pruning as possible be given the growing tree and that only for the purpose of directing growth. We cannot in any practical way stimulate the growth of one part of the tree beyond the rest. The only way to keep the various parts of the tree symmetrical is to prune the part that is growing too fast. Probably cutting back is more effective than thinning out, when one is forced to check the growth of a branch that is outgrowing its neighbors.

Always one must prevent the development of equal forks. By this is meant forks of two or more branches of approximately equal size. Such unfortunate conditions are frequently found where a young tree is cut back at planting and the several branches that arise from the shortened trunk are allowed to develop equally. Sooner or later one or more of these branches splits off with a load of fruit, seriously damaging the tree. This condition is prevented if the side branches are kept subordinate to the leader by pruning or perhaps removing some of them. Similarly one must deal with equal forks wherever they appear in the tree. One branch should be cut back severely or entirely removed, and the earlier it is done the better.

EFFECT OF THE STOCK ON THE SCION

By J. S. BAILEY

The variability of seedling root stocks for the apple and the desirability of having trees propagated on vigorous roots have been recognized for years. But not until recently has experimental work been started to seek out desirable root stocks and practical methods of propagating them.

This is a report of progress of work being done at the Massachusetts Agricultural Experiment Station to ascertain the effect of several stocks on various scions and to find a hardy, vigorous, uniform stock suitable to be used in the propagation of our common commercial varieties.

To show the extreme variability in yield of apple trees propagated on seedling stocks, the following data have been taken from reports of the Pennsylvania and West Virginia Experiment Stations. Table 1 gives the total yield in bushels from 1908-1918 of individual trees in a York orchard planted in 1888 in Pennsylvania. The orchard was in sod and the trees whose yields are included in the table were all treated alike and had no fertilizer. The arrangement of the figures in the table corresponds to the location of the trees in the orchard.

Table 1

13 bu.	4 bu.	16 bu.	5 bu.		7 bu.	
24		41		50 bu.		35 bu.
41	34		20	30		
31		49	37	25	17	
15	25		14	17		

Some Grimes trees in a West Virginia orchard show even more striking contrasts. Of two trees growing side by side and getting exactly the same treatment, one yielded a total of 36 bushels and the other 3 pounds for a ten-year period. Still another pair yielded 38 bushels and 2 bushels for the ten-year period.

The Maine Experiment Station has concluded from data collected over a long period of years that in any one year 35 per cent of the variation in yield is due to seedling stocks and 65 per cent to soil differences.

With the object of eliminating the 35 per cent of variation due to seedling stocks, the Massachusetts Experiment Station started in 1912 an experiment to grow a number of varieties on known roots. That is, trees were started on seedling roots and after roots had been sent out from the scion, the seedling roots were cut off. These scion rooted trees were then used as the stocks in this experiment.

After the stocks had been obtained the orchard now known as the Root and Scion Orchard was planted in 1915. This orchard consists of over 1100 trees. The main part of the orchard, 685 trees, consists of the following top and root varieties:

Top Varieties	Root Varieties
Red Astrachan	Own rooted
McIntosh	Ben Davis
Yellow Transparent	Bough (Sweet)
Baldwin	Northern Spy
Wagener	Red Astrachan
Tolman	Wagener
	Wealthy
	Oldenburg (Duchess)
	Yellow Transparent
	English Paradise

The balance of the orchard consists of various other varieties on a number of different stocks.

The growth of the trees has already given us some striking results. Figure 1 shows the average trunk diameter in 1924 of the six main varieties on ten different stocks.

The first thing noticeable in this figure is the larger growth of the own rooted trees of the more vigorous varieties,—Red Astrachan, McIntosh and Baldwin. Special attention is called to McIntosh on its own roots, which is much superior to McIntosh on any other root. See Fig. 3, Plate I.

In contrast to the good growth of the own rooted trees, notice the very poor growth of all varieties on Oldenburg roots. This poor growth has been consistent throughout the experiment. It is probably due almost entirely to a lack of vigor of the stock although incompatibility of stock and scion may have had some influence also. Fig. 4, Plate I, shows a McIntosh tree on Oldenburg roots. Compare this with Fig. 3, Plate I.

The Northern Spy has always been considered a desirable stock in this country where it has been grown on seedling roots and then used for top-working. In South Africa and Australia where it has been used as a root stock to resist the attacks of woolly aphis, it is considered a dwarfing stock. In Fig. 1 it shows up as being fairly vigorous. Trees on this stock grew much more vigorously in 1923 and 1924 than previously. The weak growth of trees on Northern Spy during the first few years was probably due to Hairy Root, a form of Crown Gall with which most Northern Spy stock was infected. It is probable that the Northern Spy is a vigorous stock after it has grown sufficiently to overcome the effects of Hairy Root.

Crown Gall is not confined to the Spy stocks. Most of the others are infected more or less with some form of it. Data will be collected later to determine how much it has affected the results.

The Bough stocks show up in Fig. 1 rather better than the Northern Spy stocks. This difference will probably be reversed in the next few years. as the Bough stocks have behaved just the reverse of the Northern Spy. They were the easiest to root of any of the stocks and grew so well the first few years that they got a big start over most of the others. But the past two or three years the trees on Bough stocks have been slowing down in their growth as compared with those on most of the other stocks.

Tolman trees on their own roots are really not as poor, after they get

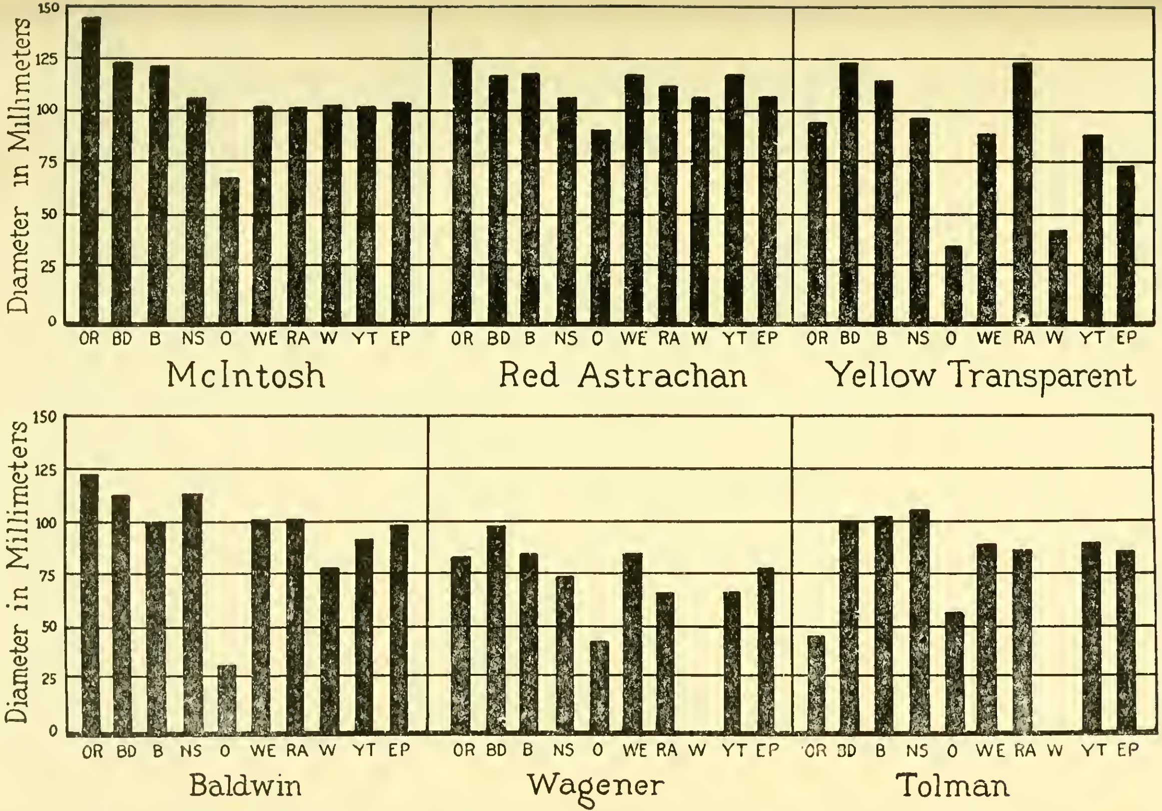

Fig. 1. Average trunk diameter in millimeters of the six top varieties on the several stocks—1924.

O. R.	Own rooted	N. S.	Northern Spy	R. A.	Red Astrachan	Y. T.	Yellow Transparent
B. D.	Ben Davis	O.	Oldenburg	W.	Wagener	E. P.	English Paradise
		'B.	Bough	WE.	Wealthy		

started, as Fig. 1 indicates; for during the years 1923 and 1924 they made more growth than Tolman trees on any other roots. The difficulty lies in getting the Tolman roots started. This was the hardest of any of the varieties to root from the scion, and therefore was under a great handicap when the trees were set.

The English Paradise stocks have not done as well as Fig. 1 indicates. They made a fairly rapid growth at the start but slowed down very noticeably during 1923 and 1924. The tops are small and in some cases, such as with Tolman, show a very characteristic shape. (See Fig. 5, Plate II.) Notice the flat spreading character of the top. Compare this with the upright growth of Yellow Transparent on the same stock (Fig. 6, Plate II.)

In regard to the effect of the different stocks on bearing, no conclusions can be drawn at the present time as the trees have not borne enough crops to determine what their actual performance will be. Figure 2 shows the average total yield for the years 1922, 1923, and 1924.

This figure shows four things in regard to earliness of bearing. First, the dwarfing stock, English Paradise, brought most of the varieties into earlier fruiting than any of the other stocks. Second, Oldenburg stocks have not brought any of the varieties into early bearing. This is because the tendency toward late bearing, due to lack of vigor, completely outweighs the tendency toward early bearing, due to the dwarfing effect. Third, McIntosh on its own roots has borne earlier than McIntosh on any other root. This is due to the exceeding vigor of the McIntosh roots which have brought the tree to bearing maturity more quickly than any other roots. Fourth, the Northern Spy root has had the effect of a dwarfing stock on McIntosh and brought it into early bearing. As has already been pointed out, the growth records show that this dwarfing effect is not permanent.

From this work it is concluded that the effect of the stock on the vigor of the scion depends on (1) the vigor of the stock; (2) the readiness of rooting of the stock, though this is only temporary; and (3) "the degree of success of union between the stock and scions."

It follows, then, that a uniform vigorous hardy stock which can be propagated by vegetative means is needed to replace the seedling stock now in use for the propagation of apple trees. This problem has been taken up by the United States Department of Agriculture and the Pennsylvania Experiment Station, as well as by the Massachusetts Experiment Station.

In the spring of 1924 this Station imported from the experiment station at East Malling, England, 800 stocks of 17 types. These types had been selected from apple stocks commonly grown on the European continent. They range from very dwarfing stocks to free growing standard stocks, all of which, it is said, can be vegetatively propagated by means of mound layers. Some of these imported stocks were used for increasing the supply, and others were budded to McIntosh and Wealthy in August, 1924. It is hoped that among these stocks one or more will be found which fills the requirements of a good stock.

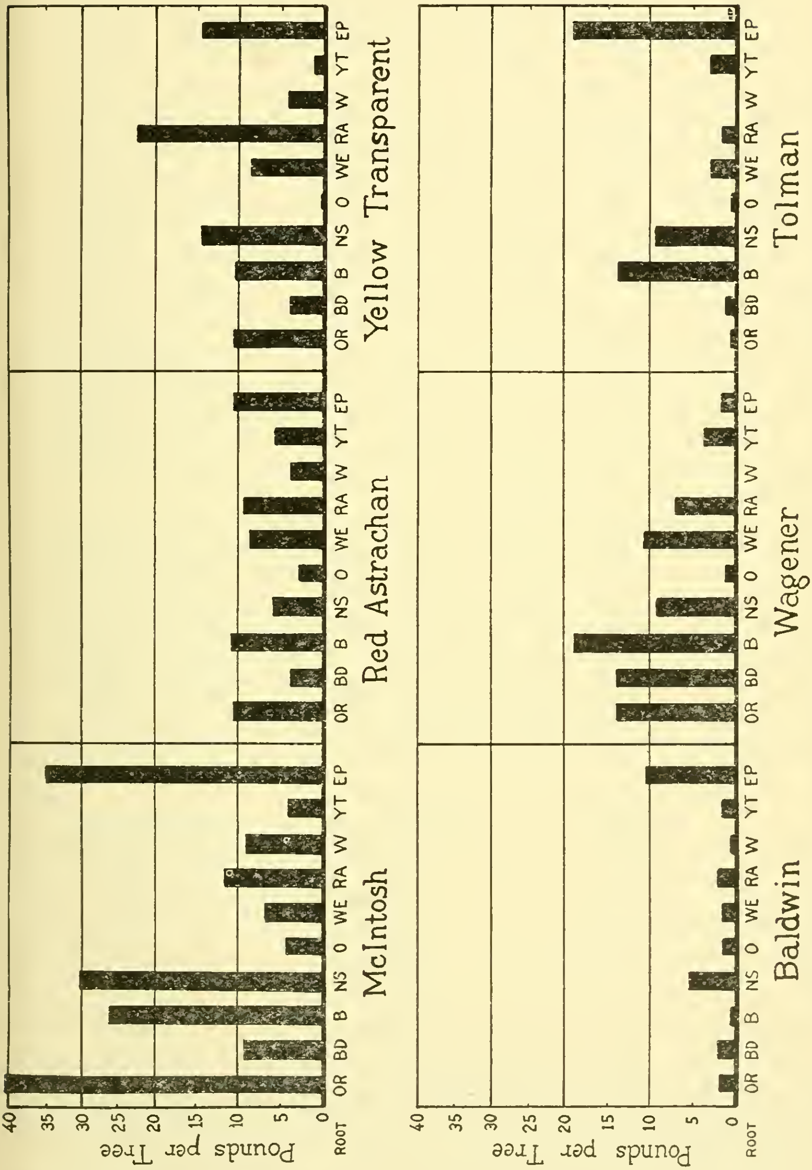

FIG. 2. Average total yield in pounds of the six top varieties on the several stocks—1922-1924, inclusive.

O.R.	Own rooted	N.S.	Northern Spy	R.A.	Red Astrachan	Y.T.	Yellow Transparent
B.D.	Ben Davis	O.	Oldenburg	W.	Wagener	E.P.	English Paradise
B.	Bough	WE.	Wealthy				

THE PROGRESS OF NURSERY TREE CERTIFICATION

BY J. K. SHAW

The certification of varieties of fruit trees for trueness to name rests on the possibility of recognizing varieties by the trees in the nursery row. That varieties could be so recognized has long been more or less well known to nurserymen.

Special studies of varieties of apple trees were begun at this station about 1912, in connection with the project for the study of the Interrelation of Stock and Scion in Apples. By 1920 the writer had become convinced that it was possible to detect misnamed trees in the nursery row with practical certainty. In June, 1921, a meeting was called to consider the possibility of certifying nursery trees and thus minimize or eliminate the misnamed tree that had been a source of considerable loss to fruit growers of Massachusetts and other states, also to nurserymen and tree dealers. At this meeting were representatives of the Department of Pomology of the College and Station, the State Department of Agriculture and the Massachusetts Fruit Growers' Association. The possibilities of certification were discussed and a tentative plan of operations outlined. At a meeting held at Amherst in August, 1921, the Massachusetts Fruit Growers' Association voted to sponsor this plan, and it was first put in operation in September, 1921, and has been continued on a constantly enlarging scale each succeeding year.

For the first two years, work was done in Massachusetts nurseries only. It soon appeared that little progress could be made unless the work was extended to nurseries outside the state, because only an insignificant portion of the trees planted in the state are grown here. Consequently arrangements were made in 1923 to certify trees for a western New York firm that sells a considerable number of trees to Massachusetts growers. In order to avoid a possible charge of favoring any particular nurserymen, certification was offered in 1924 to any nursery desiring it, and this policy has since been followed. The following table shows the development of the work:

Year	Number of Firms	Number of Trees Certified	Number of Trees Refused Certification
1921	1	2580	267
1922	2	8437	435
1923	3	65910	905
1924	6	125609	3505
1925	13	166810	9250
Totals		369346	14362

The nursery firms now cooperating in the certification work sell a large proportion of the trees bought by Massachusetts growers. It is therefore possible for any grower in the state to buy trees with this increased assurance of their being true to name. Too much stress should not be laid on the number of trees refused certification. While it is certain that practically every one of these was not true to the nursery record or label, many of them were known to the nurserymen and would not have been sold under wrong names; in most cases, however, it was a surprise to the nurserymen to learn of these misnamed trees. On the

PLATE I.

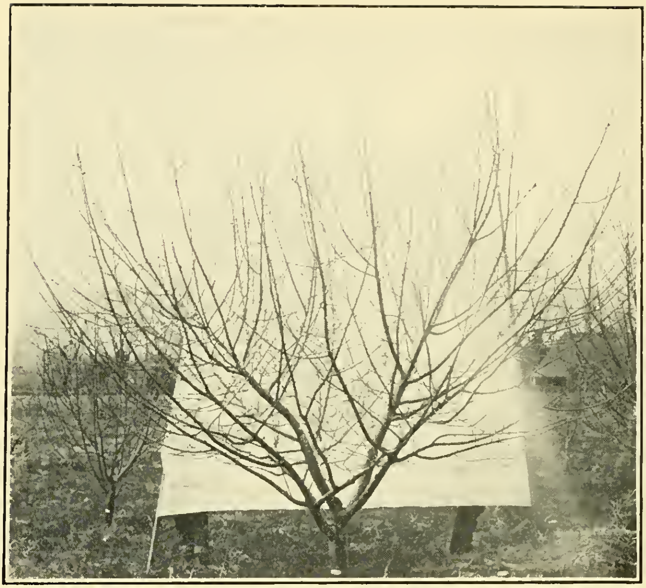

FIG. 3. McIntosh on its own roots.

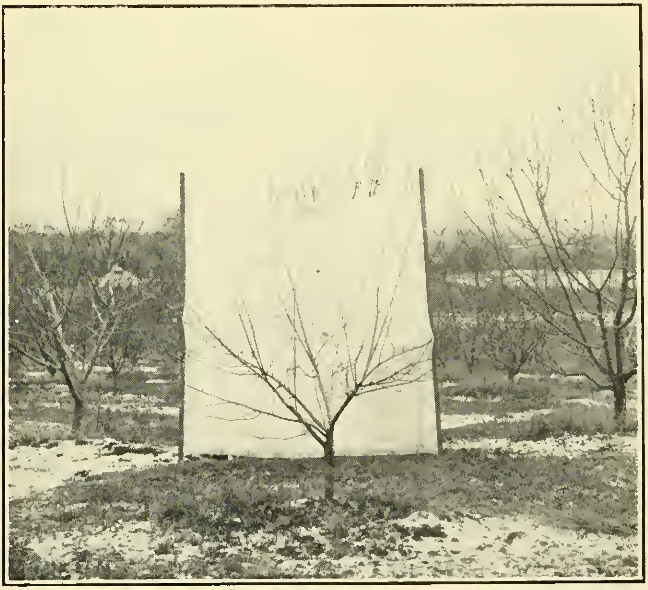

FIG. 4. McIntosh on Oldenburg roots.

(Figures 3 and 4 are on approximately the same scale. The apparent difference in the size of the screen is due to the fact that in Figure 4 the screen was held considerably farther from the tree than in Figure 3.)

PLATE II.

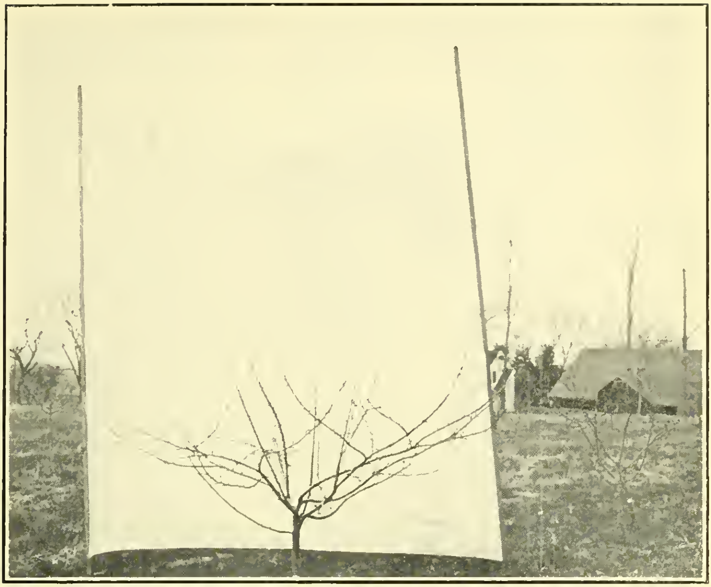

FIG. 5. Tolman on English Paradise roots.

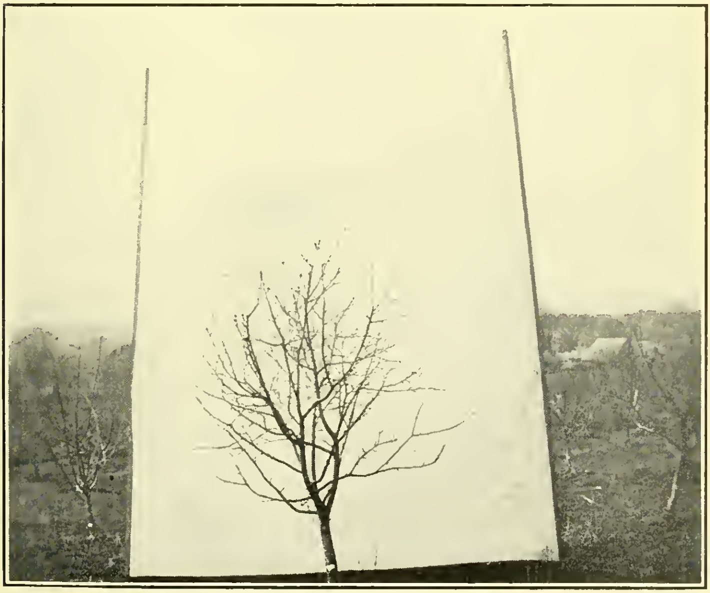

FIG 6. Yellow Transparent on English Paradise roots.

other hand, we have no means of knowing how many mistakes may be made in digging and shipping the trees. Such errors are absolutely eliminated with certified trees. Many more trees have been examined than certified and the misnamed trees among these are included in the above table.

Certification is carried on by the Massachusetts Fruit Growers' Association. The Experiment Station has no official connection with it though it has given moral support and cooperation. Any nurseryman desiring certification may apply to the Association and an agent qualified to distinguish varieties visits the nursery during the late summer or early fall and personally examines the trees. To such as are found to be true to name a lead seal is attached by drilling a one-sixteenth inch hole through a branch, or in case of one-year trees through the trunk. The name of the variety (usually in abbreviated form), the word "certified" and on the reverse side the letters "M. F. G. A." and the year in which the work was done are stamped on the seal with a hand seal press. *All trees certified by the Massachusetts Fruit Growers' Association bear this lead seal.* The work of attaching seals is done by employees of the nursery, working in gangs of four. One gang will seal from 2,000 to 4,000 trees per day. The cost of the work is met by the nurserymen. It has varied greatly with conditions, but with the larger jobs has probably been from $18 to $25 per thousand trees certified, including the cost of attaching seals.

For the first two years only two-year apple trees were certified but later one-year trees were included. The number of varieties has gradually increased until now nearly forty are included. Pear and plum varieties were taken on in 1925 though only a few trees were certified.

All nurseries examined thus far have contained trees not true to name, but the proportion has varied from less than 1 per cent to more than 10 per cent. As the work in any one nursery continues the number of misnamed trees naturally decreases, but new mixtures may appear from year to year.

This plan of certifying trees to be true to name is not infallible. It depends upon the human eye and brain and they are not perfect. The chances of error are, however, slight and it is confidently believed that the number of errors made is insignificant. No such cases have yet been brought to the attention of the Association. Variety certification is in operation in Canada and in California and is under consideration in other states. It is believed that it is the best plan of eliminating the misnamed tree yet brought forward. Every nursery firm starting the work has continued it in succeeding years.

THE CODLING MOTH IN MASSACHUSETTS

BY A. I. BOURNE

The codling moth is one of the worst insect pests with which orchardists of Massachusetts have to contend. In spite of thorough and careful spraying, the annual loss from its ravages continues very high.

The life history of the codling moth in Massachusetts has been approximately known for years, and general methods for its control practiced; yet fruit growers have been annually confronted with very considerable losses which have come mainly from so-called "side worm" injury. Such a condition of affairs led the Station to engage in a study of the insect, with particular reference to determining the proper timing of the "cover" sprays following the calyx spray.

It was at first supposed that this "side worm" injury was due almost altogether, if not entirely, to second brood larvae. Consequently attention was at first directed toward determining the approximate date when this brood appeared, and also its relative size and importance. As the project developed, it became evident that a more accurate knowledge of the entire life history of the insect was necessary, if a satisfactory solution of the problem was to be reached. Beginning with 1923, therefore, the complete seasonal history of the insect has been followed. Some of the more important events in the life history of the insect, as recorded for the three seasons, are summarized in the following table:—

Table 1. Development of the Coddling Moth, as recorded in 1923, '24 and '25.

	1923	1924	1925
Beginning of spring pupation	May 3	May 3	April 24
Date of last pupation	June 26	July 11	June 20
Duration of pupa stage	8-24 days	12-23 days	8-24 days
Emergence of first moths	May 27	May 24	May 12
First period of maximum emergence	June 2-4	May 26-30	May 16-18
Second period of maximum emergence	June 20-24	June 22-27	June 3-9
Date of last emergence	July 2	July 24	July 3
Duration of egg stage	5-10 days	4-12 days	4-11 days
Emergence of second brood moths	July 20-Aug. 29	July 21-Sept. 2	July 11-Aug. 28
Period of greater emergence	Aug. 3-6	Aug. 4-9	July 31-Aug. 12
Appearance of second brood larvae	Aug. 1-Sept. 6	Aug. 2-Sept. 17	July 24-Sept. 12

Comparison of the dates of the development of the insect, as shown in Table 1, with the seasonal development of the apple during the three-year period is noted below:—

Table 2. Comparison of the seasonal development of the apple with that of the codling moth.

Apple Development	Codling Moth Development
Blossom buds showing pink	Beginning of pupation
Pre-pink spray	———
———	Moths appearing (1-6 days before calyx spray)
Calyx spray	First period of maximum appearance of moth
3-4 weeks later (2-3 weeks in 1925)	Second period of maximum emergence of moth

In general the weather conditions prevailing during 1923 and 1924 were very similar, particularly as regards the frequently recurring periods of cold and unfavorable weather in May. These retarded the normal advance of the season and caused a corresponding slowing up of development on the part of the codling moth. In 1925 insect activities commenced fully a week to ten days earlier than in the two previous years, and held this advantage throughout most of the season. This difference is reflected in Table 1 above, where it will be noted that the dates of various steps in seasonal development of the insect for 1923 and 1924 were nearly the same, while in 1925 they were about ten days earlier. It naturally followed that first brood larvae began to mature and leave the fruit that much earlier than usual, so that a larger proportion formed pupae and emerged as second brood moths.

During the last three years it has been possible to follow the seasonal development of the insect in the eastern part of the state, through the assistance of Mr. A. N. Calkins of Harvard. Thus far there has been found to be very slight difference between the two points, a matter of two or three days in either direction being the most thus far noted.

In a survey of the results to date, certain outstanding facts are significant. There have been, each year, two widely separated and distinct periods of abundance in the emergence of first brood moths. The first coincides very closely with the time of the calyx application. By careful spraying at this period, growers have been able to practically eliminate "blossom end" injury, and cut down very largely the danger of a serious second brood.

In the last three seasons there has been a second great peak of abundance which, from our records, may contain the greater part of the total emergence. This second peak in 1923 and 1924 occurred three or four weeks after the first. In 1925 the period was shortened by the extremely hot weather early in June. The main damage caused by the codling moth at the present time appears to be largely due to this irregularity in the emergence of moths and consequent long-drawn-out appearance of first brood larvae. This causes the early "side worm" injury which has been so prevalent in late years.

It is clear that any spray to be effective under such conditions must be timed so as to kill a maximum number of larvae before they enter the apple, and emphasizes the need of the cover or post-calyx spray. This needs to be applied very thoroughly since we have found that young larvae, on their way to enter the fruit, will feed to some extent on the foliage. In the years 1923 and 1924, this would have properly been applied about four weeks after the calyx spray. In 1925, due to the speeding up of development from the hot week in June, this spray would have been timed about three weeks after the calyx spray. It is worthy of note that those growers who sprayed during or just after that week reported very clean fruit in those blocks treated.

As our knowledge of the habits of this insect develops, more than one spray during this period may be found advisable, to give continuous protection during the long period over which infestation of fruit may take place. A survey of some orchards in the main fruit growing sections of the state brought out the fact that growers who made two or more applications of either spray or dust at two-weeks intervals after the calyx application reported early "side worm" injury almost negligible.

Growers have come to believe that the calyx and one or two cover sprays after the calyx will so control the pest that the probability of a serious second brood can be ignored. Ordinarily this may prove true. In 1925, however, there developed a comparatively large second brood, throughout the state, with a serious amount of late "side worm" injury, due very largely to the reasons mentioned earlier in this paper.

From the data at hand, this second brood appears at about the same period every year, regardless of whether the season has been "early" or not. If the grower depends on a single application aimed to control the pest at this stage, dusting or spraying early in August would appear to give him best results. Some growers this season made an application at this time, and succeeded in reducing late "side worm" injury in those blocks very successfully.

For successful control of this pest, from our present knowledge of its life history and habits, certain steps are essential:—

1. A thorough application of the calyx spray. This is very important. Upon it depends freedom from "blossom end" injury, and lessening the danger of a large second brood.

2. The cover or post-calyx spray is almost equally important. It demands even more care from the grower as to the proper time of application. Upon this depends protection over the long period during which larvae are appearing, and relief from early "side worm" injury.

The exact date for this spray, and the number of applications that may be necessary cannot be stated absolutely. These must be determined each season, as they are governed largely by weather conditions From the experience we now have, two applications at intervals of two weeks after the calyx spray have given excellent results. A third application may be advisable should the season be unusually "early."

3. If the season is "early," there will be the probability of a large second brood. The bulk of this brood apparently comes about the first of August each year, whatever the type of season up to that time. With a brood of such size as that of 1925, a special application in early August is necessary to avoid serious late "side worm" injury.

TESTS OF LIME-SULFUR SOLUTION AND SOME OF ITS SUBSTITUTES AGAINST SAN JOSÉ SCALE

BY A. I. BOURNE

While under eastern conditions, at least, lime-sulfur solution has long been recognized as the standard dormant spray for the control of San José scale, yet fruit growers are much interested in the various dry powders now offered as substitutes for the concentrated solution. Transportation charges are less, there is no danger of freezing and no loss from leakage. Used in strengths recommended, these dry powders furnish less polysulfide sulfur than does the concentrated liquid used at standard dilution of one part to eight parts of water.

This situation led the Experiment Station to undertake a test of these different materials with the purpose of finding whether the dry materials are effective, and how dilute the liquid concentrate may be used and still be effective, for scale control.

All the materials used in the tests were of standard brands purchased in the open market. A chemical analysis of each brand was made, as shown in Table 1.

TABLE 1. Polysulfide sulfur and free sulfur in the materials tested.

	Polysulfide Sulfur, Per cent.	Free or Inert Sulfur, Per cent.
Lime-sulfur solution (33°+Beaume)	25+	—
Dry lime-sulfur	55+	6
Sodium sulfur compound	41+	3
Barium sulfur compound	21+	15

The materials were used at the strengths recommended by the manufacturers for scale control, and printed on the label or the container;

and were applied in liberal amounts to insure a thorough covering of all parts of the trees.

The materials were applied each year as "delayed dormant" sprays, and results were determined by microscopic examination of sprayed and unsprayed trees, the number of dead and living scales present being recorded. Counts were made a few weeks after the sprays were applied, but well before the time of appearance of the crawling young. During the course of the tests more than 10,000 scales were counted, this being the basis upon which conclusions were drawn as to the effectiveness of the different materials and dilutions.

Preliminary tests the first season indicated conclusively that dilutions of the liquid concentrate of 1 : 16 or beyond would not give satisfactory control of the scale. Further tests at or beyond this dilution were therefore omitted. The results of the three seasons' tests are summarized as follows:

TABLE 2. Results of tests with various sulfur sprays for the control of San José scale.

		Scale dead, Per cent.
Lime-sulfur solution	1 : 8	97
	1 : 9	97
	1 :10	97
	1 :11	95
	1 :12	94-95
	1 :14	86-87
Dry lime-sulfur		93
Sodium sulfur compound		92-93
Barium sulfur compound		90-91
Unsprayed check		74-75

It was noted, during the three seasons, that there was considerable variation in the percentage of scale which lived through the winter. This ranged from about 21 to 28 per cent, and seemed closely associated with the type of winter experienced. For the three-year period, the average winter mortality was close to 75 per cent, which figure is doubtless about what we may expect to occur under Massachusetts conditions.

This difference in the percentage of scales which died during the winter caused some variation in the estimates of relative efficiency of the sprays, from one year to another. Over the entire period, the relative contro value of the different sprays as compared with the untreated checks i shown in the following table:

TABLE 3. Relative control value of the different sprays.

		Effective Control, Per cent.
Lime-sulfur solution	1: 8	88
	1: 9	88
	1:10	88
	1:11	80
	1:12	80—
	1:14	50+

Dry lime-sulfur	72
Sodium sulfur compound	70-72
Barium sulfur compound	60-64

From the above, it is evident that in these tests the liquid lime-sulfur concentrate diluted 1:10 proved equally effective to the 1:8 strength. There was a distinct falling off with the 1:11 and 1:12 strengths, and a sharp decline in killing efficiency at the 1:14 dilution. The dry lime-sulfur and sodium sulfur compound proved about equally effective, but did not give quite as good a kill as the 1:12 dilution of the concentrate. The barium sulfur compound fell considerably below the two others in killing efficiency, and proved but little better than the concentrate at 1:14.

In no case did any of the dry sulfides equal the concentrated lime-sulfur solution, 1:8 or even 1:12, in killing the scale. It is evident, therefore, that the dry materials must be used at strengths higher than those recommended, to bring their killing efficiency up to that of lime-sulfur solution. There are two drawbacks to any such plan:

1. Any material increase in dosage will bring the cost of the dry materials to a very high figure as compared to that of the lime-sulfur solution.

2. There is experimental data to show that the efficiency of the dry materials increases as the dosage grows higher, only up to a certain point. Beyond this, the accumulation of insoluble matter is so great as to offer difficulties in application. Straining out this insoluble matter would doubtless relieve this difficulty, but would require an additional step in the preparation of the spray.

There has been for some time a feeling, which has led to considerable discussion, that equal amounts of the liquid lime-sulfur and of some of the dry sulfides, based on the active principles they contain, are not equal in killing efficiency.

On the basis of the polysulfide sulfur content of each of the materials used in these tests, we find the amount of polysulfide sulfur present in 50 gallons of spray to be as follows:

		Polysulfide sulfur in 50 gallons of spray, lbs.
Lime-sulfur solution	1: 8	15
	1:10	12
	1:12	10.5
	1:14	9
Dry lime-sulfur		6.6
Sodium sulfur compound		5
Barium sulfur compound		3

Comparing these figures with the table above showing the effectiveness of the materials in actual field tests, it is evident that the dry materials had a killing power much nearer that of the lime-sulfur solution than their polysulfide sulfur content would lead one to suppose; and further, that any increased dosage should be figured on the actual performance of the different materials in the field, rather than on a comparison of their chemical content alone.

It is along such a line that further work remains to be done.

From the above tests and the information we now have on these materials, certain conclusions are evident:

1. Under Massachusetts conditions, the commercial lime-sulfur solution,

if thoroughly applied, may be used at a 1:10 dilution and still maintain its high efficiency against scale.

2. At the strengths recommended by their manufacturers, none of the dry products has given as satisfactory control of scale as has the concentrated lime-sulfur solution, even when applied weaker than the usual dilution.

3. The dry materials have shown, in actual field tests, a higher degree of effectiveness as compared with the lime-sulfur solution, than a comparison of their chemical content of polysulfide sulfur would lead us to expect.

4. The dry lime-sulfur and the sodium sulfur compound were about equally effective, and greatly superior to the barium sulfur compound.

5. Great concentration of the dry materials is impractical from the standpoint not only of cost, but also of application, owing to the large amount of insoluble matter accumulating in the tank.

It should be clearly understood that the above statements refer to the concentrated lime-sulfur solution and the dry sulfides purely from the standpoint of their efficiency as dormant sprays for the control of San José scale, and have no bearing on any fungicidal value which the materials may possess.

SOME RESULTS FROM SPRAYING WITH SCALECIDE

BY A. I. BOURNE

For many years the question of oils for spray purposes has held the attention of fruit growers everywhere. Because of their effectiveness against San José scale, oil sprays have been used quite extensively, in spite of the fact that, when not properly prepared, severe injury often followed their use. This condition, at first inimical to the use of these sprays, made comprehensive research studies necessary. These have been organized under the sponsorship of the Crop Protection Institute.

The main lines of endeavor in the investigation as conducted in Massachusetts have fallen into two general classes.

1. A study of both immediate and cumulative effects of Scalecide upon various types of fruit trees common to Massachusetts orchards.

2. A study of the effect of Scalecide upon various insect and other pests, primarily those of orchard trees, and necessarily limited to the species common to this region.

The study of the different phases of plant stimulation or other cumulative effects following the continued use of Scalecide has not yet reached the point where definite conclusions can be drawn. Certain results, however, along the line of the insecticidal value of this material, which our tests have brought out to date, can be briefly reported.

Applied as dormant sprays in the spring against the winter eggs of the European red mite, with results drawn from counts of 20,000 to 25,000 mites of different stages, Scalecide and other materials showed the following relative control values, as compared with unsprayed checks:

Dormoil (a western type oil)	99 per cent
Scalecide	98-99 per cent
Sunoco	97 per cent
Rex oil emulsion	89 per cent
Lubricating oil emulsion 2%	90 per cent

In every test Scalecide has given very nearly perfect control of the overwintering eggs, when applied as a dormant or delayed dormant spray in the spring. One test made with this material applied in the fall gave a degree of control considerably less than that from spring application.

Against the overwintering egg masses of apple tent caterpillars, while not yielding such striking results as noted above, Scalecide has caused a very substantial reduction in hatch. In view of the increasing abundance of this pest throughout Massachusetts during the past few years, this beneficial effect of Scalecide is of considerable significance.

A study of the effect of this spray upon the early spring infestation of apple aphids has not been as comprehensive as might be desired, due to the scarcity of material thus far available. Results to date have indicated a very definite reduction in the numbers of plant lice, from a spring application very nearly approximating the time of hatching of the eggs; *i. e.*, the so-called "delayed dormant" period. Application as a purely dormant spray yielded very slight control of the subsequent hatch.

Spring application of Scalecide on pears yielded a very material check upon the infestation of pear psylla as based on the comparative number of eggs deposited upon unsprayed and sprayed trees. In one season there was found to be a reduction in infestation amounting to over 90 per cent on trees sprayed with Scalecide as compared with unsprayed rows alongside. The following season favorable weather conditions in early spring allowed early activity on the part of the psylla, and some eggs had been deposited before the spray was applied. Subsequent counts of eggs on sprayed blocks indicated a control of better than 85 per cent. Fall applications did not yield any striking control.

Tests made during one spring, using Scalecide diluted 1 to 20 on a small planting of ornamental spruce, against overwintering stages of the spruce gall louse, resulted in very satisfactory control of the insect and no injury to the trees.

Tests with the oyster-shell scale yielded negative results. Except for causing a possible slight delay in appearance of the newly-hatched young, there was very slight effect noted following the sprays. The difference in amount of hatch between unsprayed trees and those given the oil, if any existed, was not enough to be measurable.

In every instance the material was found to possess excellent physical qualities. It "flowed" from the container without difficulty even when the weather was cold, a feature which favorably impresses any grower who has had experience with oils. In preparation for the spray, the material offered no difficulty, mixed readily with the water, and required only moderate agitation. It formed a very stable solution from which there was little or no oil separation, even upon standing for a considerable period.

It should also be noted that, in all of our tests covering three seasons' work with Scalecide applied to several varieties of apple, pear, cherry, plum and peach, covering over two hundred trees, there has been discovered no instance of injury which was in any way attributable to the spray applied.

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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 227 — FEBRUARY, 1926

THE CONNECTICUT VALLEY ONION INDUSTRY

PROGRESS REPORTS
OF
EXPERIMENTAL WORK

This bulletin contains four papers summarizing the experimental work of the Station which is of special value to onion growers. The subjects reported upon are as follows:

The Present Status of the Connecticut Valley Onion Industry .... Lorian P. Jefferson

Fertilizers for Connecticut Valley Onions .... A. B. Beaumont and O. E. Street

Onion Blight or Downy Mildew .... A. Vincent Osmun

A Study of the Life History and Control of the Onion Thrips .... A. I. Bourne

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AGRICULTURAL EXPERIMENT STATION
AMHERST, MASS.

THE PRESENT STATUS OF THE CONNECTICUT VALLEY ONION INDUSTRY

By LORIAN P. JEFFERSON

Three crops of onions are grown in the United States, early, intermediate and late. The chief competitors of Massachusetts in the production of late onions are New York, Ohio and Indiana. The states of Colorado, Idaho and Minnesota are coming into prominence as onion growing states, but as yet they ship comparatively few onions to eastern markets. Acreage in Massachusetts decreased from 4,560 acres in 1922 to 3,190 in 1924, but in 1925 rose again to 3,820 acres. Production, despite reduced acreage remained about the same, practically 1,250,000 bushels: but the crop of 1925 was reported as 1,580,000 bushels. This indicates either an improvement in cultural methods and in care of the crop at harvest time, or an unusually favorable season.

Owing to recent very unfavorable conditions in California, Ohio and Massachusetts particularly, the total acreage of late onions in the United States was reduced some 14 per cent in 1925. The total of 37,450 acres is the lowest planted for several years.

Onion growers have recently been disturbed by the quantities of foreign onions arriving on our markets. Side by side with home-grown onions the foreign product usually commands a higher price. Inquiry among dealers, however, indicates that these onions are mostly used for different purposes. Of milder flavor, the foreign onions are chiefly used raw in salads and sandwiches.

Boston, the chief market for Connecticut Valley onions, receives large quantities from other sources. During the four seasons, 1921-1924, shipments from Spain and other foreign countries constituted an average of 13 per cent of the receipts in Boston.

The Connecticut Valley supplied 47 per cent, and New York shipped an average of 15 per cent of the receipts. However, a significant feature is the fact that New York shipments increased from 3 per cent in 1921 to 36 per cent in 1924. These arrive in quite regular shipments during the same season as Massachusetts onions.

Freight rates on onions are still favorable to Massachusetts onions on the Boston market, as compared with New York and Mid-Western states. The freight rate on 100 pounds of onions from central points in the Mid-Western onion region to Boston, varies from 55 to 69 cents, while from New York points from which onions are shipped probably 35 to 40 cents per 100 pounds is a fair average rate, onion production being widely distributed throughout the state. The rate from the Connecticut Valley is 20½ cents. If, despite the greater freight charges, growers of the Middle West and New York can compete with local onions on the Boston market, it indicates either lower costs of production or onions of superior quality.

Prices received for the 1924-25 crop were practically the same for New York and Massachusetts onions.

The accompanying tabulation presents figures for acreage and production in Massachusetts, and in three states which are her chief competitors in the production of late onions, with totals for the entire late crop in the United States.

Acreage and Production of Onions in

Massachusetts and Chief Competing States, 1921-1925.

Acreage.

	1921	1922	1923	1924	1925*
Massachusetts	4,500	4,560	3,360	3,190	3,820
New York	7,280	7,740	7,550	7,600	8,640
Ohio	5,080	5,680	5,760	6,240	2,860
Indiana	4,180	5,620	6,300	6,910	4,580
Total late crop in United States	43,560	47,320	46,720	46,580	37,450

Production (Bushels).

	1921	1922	1923	1924	1925*
Massachusetts	1,250,000	1,254,000	1,284,000	1,244,000	1,528,000
New York	2,184,000	2,090,000	3,156,000	3,192,000	3,300,000
Ohio	1,143,000	2,272,000	1,457,000	2,184,000	698,000
Indiana	1,108,000	2,321,000	2,218,000	1,728,000	1,411,000
Total late crop in United States	9,446,000	12,927,000	12,867,000	12,561,000	12,578,000

* Estimates.

FERTILIZERS FOR CONNECTICUT VALLEY ONIONS

By A. B. BEAUMONT and O. E. STREET

Within the last third of a century the Massachusetts Agricultural Experiment Station has conducted a number of experiments with the onion crop. These studies have dealt with problems of soil fertility, use of fertilizers, plant diseases, insect pests and marketing. In this paper, experiments dealing primarily with soil fertility and fertilizers are reviewed.

Field experiments here reported were conducted on the Station grounds at Amherst. The soils on which onions have been grown vary from fine to very fine sandy loam, contain a small to fair amount of organic matter, are slightly to strongly acid, and occur at elevations of 200 to 250 feet above sea level. The field experiments are divided into two groups for discussion. The first or early group extended over the period 1894 to 1917. This is the larger group. The second group was started in 1925 on the lower portion of the new Station farm known as the Brooks Farm. This second group of experiments is presented first.

After a conference with some of the leading onion growers of the Connecticut Valley, constituting an Advisory Committee on onions, field experiments planned to answer the following questions were laid out:

1. Cover crops: Is it practicable to grow cover crops in onion fields of the Valley? If they can be grown have they any value in respect to hastening maturity of the crop and maintaining fertility? What crops can be grown?

2. Lime: How much lime is necessary for best results with onions? Are large amounts injurious?

3. Fertilizers: (a) What is the best ratio of ammonia, phosphoric acid and potash in mixed fertilizers for onions? (b) Is there any advantage in applying fertilizers at different times within the season instead of all at the beginning?

4. Varieties: What varieties of onions are best suited to the Connecticut Valley? Do varieties run true to name? Can desirable varieties be maintained under Valley conditions? What are the best sources of seeds and sets?

Since the experiments have run only one year, and since the attack of mildew coming August 8 practically ruined most of the crop, only progress and incomplete results can be reported. It can be stated:

(1) That timothy, red and crimson clovers can be grown as cover crops in onions, if seeded immediately after the last shove hoeing and not later than July 26. These crops made considerable growth before the ground froze. Biennial sweet clover made poor growth as a cover crop.

(2) Moderate applications of lime, equivalent to one ton ground limestone, gave small increases in yields of onions. Large applications, up to seven tons per acre, showed no additional advantage.

(3) Complete fertilizers rather high in phosphoric acid and fairly high in potash gave the best results. Rate of application was 2500 pounds per acre. That fertilizer having the ratio of 1:3:2 for ammonia, phosphoric acid and potash gave the best yield. The fertilizer had the grade of 4-12-8.

(4) Concentrated complete fertilizers carrying a total of 32 per cent plant food can be used for onions. The 8-16-8 grade was used.

(5) No advantage was gained by the application of fertilizers at different times throughout the growing season instead of all at the beginning.

(6) Source of seed is an important consideration in the selection of seed stock. This was strikingly brought out by the difference in resistance of certain stocks to the attack of the mildew.

In considering this brief report of progress of this second group of field experiments with onions it should be borne in mind that on some points the results are not conclusive but merely indicative. Further, the land on which the plots are located had received very little cultivation for a number of years. It is probable that several years will be required to put it into a condition that is representative of our typical onion land.

The earlier group of field experiments had for their main objective information as to the kind of fertilizer materials required to grow a good onion crop. This objective was the one common to many field experiments conducted throughout the country during the period of early development of agricultural experiment stations. It was not known at the time the experiments started, whether one needed to feed the onion a single or a mixed ration of fertilizers; or which if any one of the plant food nutrients is the most important; whether lime is necessary for onions; etc. Some of these and other questions of plant feeding were answered by the earlier experiments.

The results are summarized as follows:

(1) On Connecticut Valley soils that have been cropped for a number of years, onions cannot be successfully grown unless a complete fertilizer, or one carrying ammonia, phosphoric acid and potash, at least, is used. There is still unanswered the question as to the necessity of sulfur, but since it is ordinarily present in a complete fertilizer the question is not at present very important.

(2) Fertilizers carrying ammonia entirely in the form of certain chemicals were found to be as good as those carrying ammonia in organic form

only. The significance of this fact may, however, be questioned, and for two reasons: (a) as used, neither treatment produced a large crop; and (b) the usual practice of combining organic with inorganic nitrogen was not included in the experiment.

(3) Nitrate of soda proved to be better than sulfate of ammonia as a carrier of ammonia when there was a deficiency of lime in the soil. Most of our Valley soils are deficient in lime. If lime is supplied in sufficient amounts, ammonium sulfate is as good as nitrate of soda for onions.

(4) Moderate applications of lime in practically all cases were matched by increased yields of onions. This response to lime was particularly marked when ammonium sulfate and muriate of potash were used in combination. Moderate applications (1 to 2 tons) to onions lose most of their effect within four years.

(5) There is little choice between muriate and sulfate of potash as carriers of potash for onions unless there is a great deficiency of lime, when the sulfate is preferable.

(6) Onions have responded well to fertilizers carrying a large proportion of soluble phosphates. A high proportion of phosphoric acid reduces but does not do away with the need of lime.

(7) From the standpoint of fertility, onions can be grown successfully with large (30 tons) applications of manure. Fertilizers used in addition to the manure have no additional advantage.

There are three conclusions common to the groups of experiments worthy of emphasis.

1. For continuous growth of onions on Connecticut Valley soils a complete fertilizer is necessary.

2. Complete fertilizers having a high ratio of phosphoric acid give best results with onions.

3. Moderate and frequent applications of lime are necessary for onions on Valley soils.

There appears to be little if any necessity of a choice of carriers for ammonia, phosphoric acid or potash provided practice is in accordance with these three conclusions.

ONION BLIGHT or DOWNY MILDEW

By A. VINCENT OSMUN

This disease caused widespread damage to the onion crop of the Connecticut Valley in 1924 and 1925. The first authentic report of its occurrence in Massachusetts was in late August, 1924. It is probable, however, that it has been present within the state for a much longer period, as it was reported many years ago from Connecticut, Vermont and New York. Our growers have indeed long been familiar with a disease known to them as "blight," the symptoms of which appear not to be different from those of the disease here under discussion. The disease was first reported in this country from Wisconsin in 1884.

Onion blight is caused by a parasitic fungus known technically as *Peronospora schleideni.* This is one of a group of fungi called Downy Mildews, and hence the name Downy Mildew is often used to designate the disease as well as the fungus which causes it.

Downy mildew attacks the onion tops, starting with a few onions in different parts of a field, and spreading from these centers of infection. In its early stages, even before the tissues are killed by its attack, the mildew may be detected in early morning when the leaves are wet with dew, or during a rain, as small violet colored patches. In the sun these patches dry out and collapse, leaving yellowish or white spots. The mildew quickly spreads over the entire leaf which becomes water-soaked in appearance, collapses and breaks over. The shriveled leaves are soon blackened by mold. Usually, new leaves develop following the first attack, and if weather conditions continue to favor development of the disease, these may also succumb. However, even with the new crop of leaves the bulb seldom attains full size, and the crop is thus reduced.

Downy mildews characteristically thrive best under moist, cool conditions, and downy mildew of onion is no exception. Periods of rain or high humidity with low night temperatures occurring between early July and late September are likely to bring on the disease, and at such times the fields should be closely watched for the first symptoms. With weather conditions favoring the disease its spread is very rapid, often considerable areas becoming affected within a few days and leaves dying within a short time after infection. It was not uncommon last season to find entire fields laid low by the disease.

Control measures for onion blight have been worked out. The various phases of control are based on (1) the ability of the mildew to live over winter in old onion refuse, (2) influence of environmental conditions and (3) susceptibility of the fungus to toxic fungicides.

(1) In order to reduce the possibilities of infection from previous diseased crops, onion refuse should be burned. A three or four year crop rotation also may be helpful in this connection.

(2) As excessive moisture favors development of the mildew, every practicable means should be taken to promote the drying off of the onion tops following periods of high humidity. Under-drainage, clean culture, exposure to prevailing winds, all help in drying off a wet field.

(3) Spraying with 4-4-50 Bordeaux mixture with three pounds of resin fish-oil soap added as a sticker is effective if the applications are sufficiently prompt, thorough, and frequent. If spraying is to be the program, the weather conditions should be closely watched, as the first application must anticipate appearance of the mildew. All tops must be thoroughly covered by the fungicide, and spraying should be repeated at least once a week or every three or four days if weather conditions favoring spread of the disease are prolonged.

Onion growers are not equipped with adequate spraying machinery, if indeed such machinery is in existence. Yet there can be no doubt that downy mildew will continue to attack the onion whenever moisture and temperature conditions suited to its development occur. Growers must face this possibility each season and must decide for themselves whether it will be more profitable to take the loss from possible reduction of yield, or apply the control measures above outlined.

A STUDY OF THE LIFE HISTORY AND CONTROL OF THE ONION THRIPS

By A. I. BOURNE

The onion thrips is, without question, the outstanding insect pest of the onion. In cases of severe outbreaks, the losses it has caused have often been rated as high as 25 to 50 per cent of the crop. The injury, variously termed *blast, white blight,* and *silver top,* results from these minute insects extracting the plant fluids, by means of their rasping and sucking mouth parts.

Throughout the Connecticut Valley, the main onion growing section of Massachusetts, this pest has, during late years, become very generally established and appears in large numbers annually. Previously, its ravages were chiefly confined to occasional outbreaks, many times of only local importance. With the increased acreage devoted to set onions, the thrips has come to be an annually recurring pest, and gives every evidence of increasing abundance.

Relation of Set Onions to Thrips Injury

The very close correlation of the set onion industry to the problem of thrips injury to onions grown from seed is generally recognized. Set onions on the average develop several weeks earlier than the crop of seed onions. Sets, therefore, serve as ideal nurseries for the colonization and multiplication of the thrips. The insects are thus supplied with an abundance of their favorite food plant, and consequently are able to reach large numbers comparatively early in the season. From actual counts made in the field, of the thrips colonized on nearly mature plants of set onions, it was found that two to three hundred thrips per plant were about an average, while five to six hundred were by no means uncommon. The sets themselves do not as a rule suffer severely from the attack of the thrips, since, by the time the insects have developed a heavy infestation, the plants have advanced well toward maturity and accumulated enough leaf surface to withstand the attack.

Areas given over to sets are often located close to, or even alongside, fields later planted to seed onions, so that transfer over onto the younger and smaller plants is easy. This practically assures the later development of a heavy infestation in the fields of seed onions. Observations have shown that while there is more or less of a spread from the sets before they are mature, the great movement takes place when the sets are ready to be pulled. From our studies of the life history of the insect, it was learned that the time of this general transfer usually coincides very closely with the period of greatest reproductive activity of the insect, thus increasing the danger to the fields of seed onions.

There are other sources of possible infestation—refuse and screenings, weeds, grasses, etc. The list of plants upon which the thrips has been found to feed includes many garden and field crops, ornamentals, and greenhouse plants as well as various grasses. While these are of comparatively little importance as compared with set onions, they do offer the insect ample opportunity for hibernation and early spring colonization, and explain why onion fields are often invaded from grass or weedy borders. For this reason, it is recommended to burn over, in late fall or early spring, grass and weedy areas bordering on onion fields.

Dusting for Control of Thrips

In the Experiment Station study on thrips control, various types of commercial nicotine dusts, as well as home prepared dusts, were tested. A study was made of the comparative efficiency of different strengths of nicotine in the dusts; and of the form in which the active principle was present (free nicotine or nicotine sulfate). The influence of weather conditions on the effectivness of the dusts was also studied, to determine the best time to make the applications. Different methods of applying the dusts were tried out, as well as the use of auxiliaries (hoods, curtains, etc.) to confine the dust discharged, prevent drift and so counteract the interference caused by wind.

Nicotine dusts, even those carrying a comparatively small percentage of nicotine, readily kill all the insects reached and are effective early in the season. By applying the nicotine dusts at intervals of about ten days, beginning with the first appearance of the thrips, the insects are held down sufficiently so that the plants can withstand a moderate infestation. The cost of such a practice, however, is almost prohibitive. Later in the season, the nicotine dusts are not satisfactory, since they cannot penetrate the tight crevices in the axils of the inner leaves, where a very large percentage of the thrips congregate.

Study was also made of the recently introduced calcium cyanide dusts. These possess excellent physical qualities, and the gas given off penetrates the tight crevices in the axils of the inner leaves very successfully, overcoming the thrips in practically every portion of the plant. The gas is soon dissipated, however, and a very large percentage of the thrips recover from its effects and resume normal activity. At present the cost of these dusts is high. These difficulties do not appear to be insurmountable. If the manufacturers make as rapid progress in the development of these dusts in the near future as they have in the last two years, calcium cyanide gives promise of becoming a very satisfactory control.

Spraying for Control of Thrips

In a study of the possibilities of sprays for the control of this pest. tests were made of a long list of materials, including almost every type of contact spray. Preliminary tests eliminated very many of these as ineffective or impracticable from one cause or another, and the field soon narrowed down to include the nicotine-soap combinations and certain oil sprays.

One of the greatest problems in thrips control is to reach and kill the insects deep down in the axils of the leaves (chits), where they congregate in large numbers. On account of the peculiar nature of the plant and the smooth, waxy surface of the leaves, any spray to be successful must possess excellent adhesive and spreading properties, as well as insecticidal value. Oil sprays, while very effective against all thrips actually touched, showed a very strong tendency to form into drops and roll off the plants without thoroughly covering all the leaf surface, thus forming "islands" where thrips were untouched by the spray and so escaped. Nicotine sprays used alone do not have the necessary physical qualities. When they are combined with soaps, however, they constitute a spray which possesses all of these qualifications to a very high degree.

Lack of machinery has stood in the way of successful use of sprays. The ordinary types of horse-drawn sprayers cannot be used in onion fields. The common nozzles, delivering a cone spray, have not succeeded in forcing the spray deep down into the narrow space at the base of the inner leaves. The problem was, therefore, to develop a method of driving the liquid well in among the close-standing plants and force it down into the axils of the leaves; also, to find a spray of superior wetting and flowing qualities that is toxic to all stages of the insect and has a killing action rapid enough to overcome the active winged adults.

Nicotine sulfate, the commercial 40 per cent solution, coupled with fish-oil soap, was found to answer the requirements of a spray. A small Skinner System irrigation nozzle, modified to deliver the spray at the desired angle and distribute the pressure evenly, has given good results. This delivers a thin, flat, fan-shaped spray which, with moderate pressure, is broken up into a very fine mist. The full force of the discharge is confined to a comparatively small space, so that the spray may be directed upon the portion of the plant desired, with full advantage of the amount of pressure, and with little waste of material.

This flat spray, directed upon the plants from the side, caused a vibration of the young, limber leaves which, in conjunction with the excellent wetting and flowing qualities of the spray, allowed it to work down into the tight chits and reach the thrips congregated there. From our experiments to date, a steady pressure of 125 to 150 pounds has proven satisfactory, giving a very fine mist and allowing good penetration.

The most satisfactory spray formula used was as follows:
Nicotine sulfate ("Black Leaf 40," Nicotine Sulfate 40 per cent", etc.), ½ pint to 100 gallons (1:1500), Good's No. 3 Potash Fish-oil Soap, 6-8 pounds per 100 gallons of spray.

The soap used in this formula is soft and "pourable", very easily handled and mixed into the spray. This product is of such uniform consistency that proper dilution can be made by measuring the soap as it is drawn from the container, thus allowing a saving of time when refilling the spray tank in the field. The spray made on the above formula had excellent spreading and "flowing" qualities, and covered the smooth, waxy surface of the onion tops very readily. The most promising feature was its tendency to flow down to the base of the stems and into the tight crevices, allowing the nicotine to reach and kill the colonies of thrips clustered there. In addition, the alkali of the soap served as an activator of the nicotine, thus hastening its insecticidal action.

In field tests at North Sunderland, this spray was applied to a section of a large field of onions which had become heavily infested from sets growing alongside. When the sets had been screened and disposed of, this section of the field was sprayed, using a power outfit delivering a steady pressure of 125-150 pounds, with two lines of hose operating. Owing to the heavy, driving rains and the *mildew* which had appeared in the field, some of the plants were broken down, making it difficult to make a thorough application.

Examination of the field the day following the application showed the following:

	Thrips per 100 plants	Average per plant	Control Per cent
Sprayed	165	1- 2	97+
Unsprayed	5230	52-53	—

Despite the very high percentage of control obtained, a second application has been found to be advisable, for restocking takes place very rapidly through the hatching of eggs inserted in the leaf tissues. This second spray should be applied after all the eggs have hatched, and before the first appearing larvae have matured and left the plants. Because the nicotine soap spray cuts down very materially larvae hatching for a period of at least two days after application, the period between the sprays may safely be extended to seven or eight days.

The Critical Period in Thrips Infestation

The data from field observations and life history studies revealed the fact that reproductive activity and consequently the rate of increase vary considerably during the season.

Infestation is comparatively light and shows no marked increase up to about mid-July. From that point there is a steady increase through that month, with a sudden rise to the climax of the season about the first of August. Beyond that point there is a gradual slowing up of reproductive activity for the remainder of the season.

The critical period as regards thrips infestation, therefore, occurs during late July and early August. At this time the insects have transferred in large numbers from sets and are rapidly developing an infestation on the fields of seed onions. This source of danger, coming as it does at the time of greatest reproductive activity on the part of the insect, makes this point in the season a very serious one for seed onions, and emphasizes the need of the follow-up spray to check the pest as thoroughly as possible and give greatest protection to the plants at this particular period.

Conclusion

Our studies to date have shown that the chief source of thrips infestation of seed onions is from nearby fields of set onions, and that the greatest movement of thrips takes place at the time the sets mature and are pulled. This coincides with the period of greatest reproductive activity on the part of the thrips, and comes in late July and early August.

Both from the standpoint of cost and of effectiveness, dusts do not give satisfactory control. This is true both of the nicotine dusts and of the newer calcium cyanide dusts, although the latter show considerable promise.

The usual type of spray nozzles proved unsatisfactory for this purpose, and a nozzle delivering a flat spray has been developed. This delivers the spray where it is needed, and, with a pressure of 125-150 pounds causes it to penetrate the axils of the leaves where the greatest number of thrips congregate.

Nicotine sulfate, 1-1500, with Good's No. 3 Potash Fish-oil Soap added at the rate of 3-4 pounds per 50 gallons of spray was found to give satisfactory control. A second spray application, seven to eight days after the first, has been found advisable to take care of the larvae hatched from eggs laid in the tissues of the plant.

The usual types of spray machinery are not well adapted to operate in large fields of onions. The development or adapation of an outfit which will conform to the particular requirements for the spraying of onions presents the most immediate problem.

Publication of this Document
approved by the
Commission on Administration and Finance

3000 3-'26 Order 4474.

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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 228 MARCH, 1926

AN ECONOMIC STUDY OF THE MASSACHUSETTS APPLE INDUSTRY

By HUBERT W. YOUNT and LORIAN P. JEFFERSON

According to the data reported in this bulletin, the task of marketing the Massachusetts apple crop ten years from now may be nearly double what it is today. Existing plantings, with no allowance for new plantings, indicate an increase in the apple crop, in the next ten years, ranging from 240 per cent for McIntosh down to 13 per cent for Wealthy. Were this increase to come suddenly, or without preparation on the part of growers' organizations, it might be impossible to market the crop to advantage. With knowledge as to the probable size of coming crops, growers will have not only a guide to new planting, but opportunity to develop new markets. It was for the purpose of attaining this dual objective, that the work reported in this bulletin was undertaken.

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AMHERST, MASS.

AN ECONOMIC STUDY OF THE MASSACHUSETTS APPLE INDUSTRY

By HUBERT W. YOUNT and LORIAN P. JEFFERSON

INTRODUCTION

The apple growers of Massachusetts, in common with those of the other New England States, have felt for some time the need of more definite knowledge of the apple industry—the number and ages of trees of different varieties, and the volume of the commercial crop. In order to obtain this information it was determined by a group representing the Experiment Stations, State Departments of Agriculture, the New England Research Council, the Federal Bureau of Agricultural Economics and the New England Crop Reporting Service, that a study should be made of the apple industry of New England. The purposes of this study were, specifically:

1. To secure information as to number and age of trees and the trend of planting.
2. To discover the volume of the apple crop and the amounts put on the market.
3. To discover the relative importance of each commercial variety.
4. To determine the relative importance of orchards of different size.
5. To discover common orchard practices in different producing areas.
6. To learn the relative importance of apple growing as a source of farm income.
7. To determine the relative importance of different methods of marketing.
8. To discover the extent to which grading is done.
9. To learn the prices received and the reasons for price differences.
10. To determine available farm storage space and the quantities stored.
11. To determine probable future production.

Methods and Scope

The method employed in Massachusetts was personal interview with each owner of a commercial orchard. For the purposes of this study a commercial orchard was defined as one which contained a minimum of 100 bearing trees. Exceptions were made in cases where orchards of fewer than 100 bearing trees were of evident commercial importance, or where there were considerable plantings of young trees which gave evidence of future commercial importance.

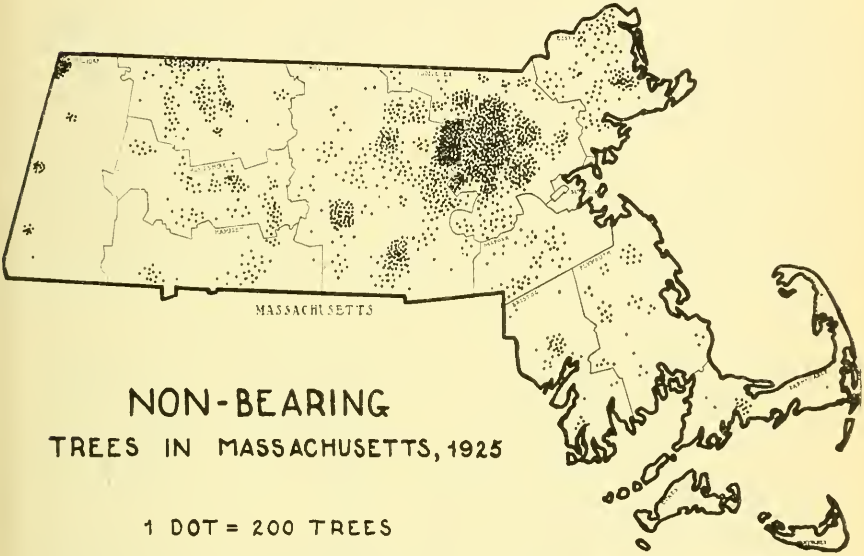
Visits were made to over 2,000 apple growers and complete schedules were secured from 1,754, which is 7 per cent of the whole number who reported apple trees in the Census of 1925. The growers visited reported 45 per cent of the trees and 55 per cent of the production as stated in the Federal Census of 1925. However, a large part of the production reported to the Federal Census is used on the farm or sold for making into cider, and it is estimated that the farms included in this survey grow over 75 per cent of the marketable apples of the state.

Cooperating Agencies

Cooperating with the Department of Agricultural Economics of the Massachusetts Experiment Station in securing this information, was the State

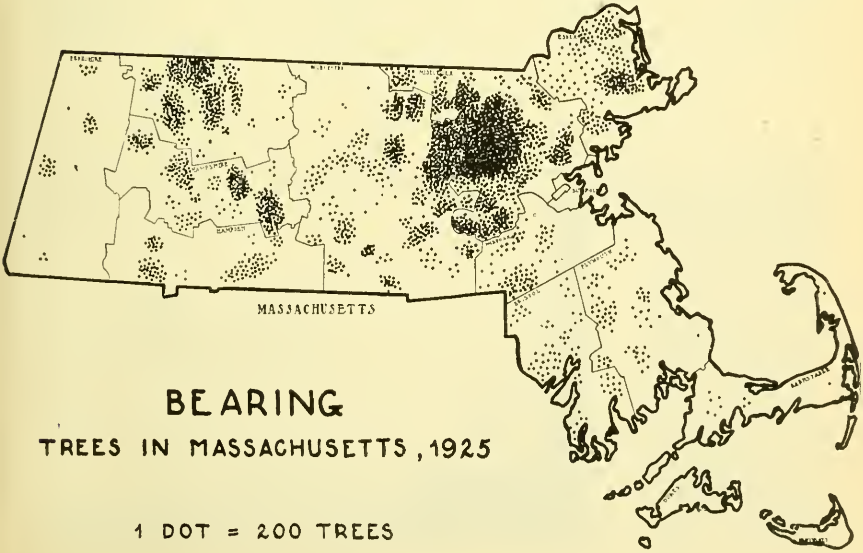
Department of Agriculture which contributed the salary and expenses of two investigators for field work. The New England Research Council acted as a coordinating agency, in order to insure the collection of uniform data throughout the New England states.

CHART 1. Non-bearing and Bearing Trees, 1925



NON-BEARING
TREES IN MASSACHUSETTS, 1925

1 DOT = 200 TREES



BEARING
TREES IN MASSACHUSETTS, 1925

1 DOT = 200 TREES

Producing Regions

Apple growing in Massachusetts centers in several rather distinct sections, although apples are grown for home consumption in every part of the state. These are Franklin County, Connecticut Valley, Nashoba area and Essex County.

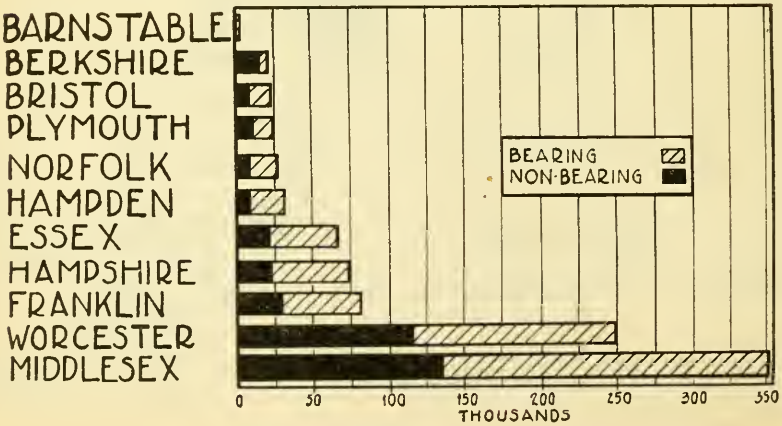
The chief section, lying partly in Middlesex and partly in Worcester counties and known as the Nashoba area, includes the towns of Littleton, Acton, Groton, Harvard, Stow, Sterling, Hudson, Boxborough, Bolton and Westford. Other towns which form a southern continuation of this area are Berlin, Marlborough, Northborough, Westborough and Millbury. Shirley, Lunenburg and Fitchburg form a similar group to the northwest. The topography of this section differs from that in other apple sections of the state, varying from fairly level to very rolling. The outstanding characteristics of this section are numerous small orchards and high production due to good orchard practice.

The Franklin County section, in the western part of the state, is included chiefly in the towns of Colrain, Shelburne, Buckland, Charlemont and Ashfield. Few growers here make apple growing their chief business, as orchards are mostly secondary to other farm enterprises. The varieties commonly grown are Baldwin and McIntosh, with a few Greening and Duchess. This region is hilly, almost mountainous in parts. Most of the orchards are irregular plantings on hillsides, trees being set in blocks in but few orchards.

Similar in many respects is the section in Essex County in the northeastern part of the state. Varieties grown here are chiefly Baldwin, with some McIntosh and small numbers of other kinds. In both Essex and Franklin counties most of the orchards are old and production is declining except in a few towns. It is doubtful if recent plantings in either of these sections have been sufficient to offset the dying of old trees.

The section in Hampden and Hampshire counties is composed of several separate areas lying on the hills along the Connecticut Valley. The towns of Cummington, Williamsburg, Easthampton and Granville form that portion lying west of the Connecticut River, while Amherst, Belchertown, Hampden and Wilbraham are included in the section east of the river.

CHART 2. Non-bearing and Bearing Trees, by Counties, 1925



In the southeastern part of the state are scattered areas consisting of a few specialized towns in Plymouth and Bristol counties. Orchards throughout this section vary greatly as to size, care and varieties. The orchards are, moreover, much scattered, some towns having none, while others grow large quantities of apples in orchards of considerable size.

Number and Age of Trees

A total of nearly a million trees was reported, one-third being not yet in bearing. Forty per cent of the trees are in Middlesex County, which with Franklin and Worcester counties produces about three-fourths of the total crop reported. The ratio of bearing and non-bearing trees varies in different sections. Only 24 per cent of the trees of Franklin County were reported as non-bearing, while in Worcester County 45 per cent are not yet in bearing. The other important counties fall between these extremes.

The estimated average age of trees reported in Massachusetts is seventeen years. There are thousands of trees from thirty to fifty or more years of age, but the great number of trees recently planted reduces the average to this low figure. According to the reports of the growers, about two-thirds of the trees are under fifteen years of age. The following table brings out the pertinent facts concerning age of trees in 1925.

Table 1. Age of Trees in Massachusetts, 1925

Age	Number of Trees	Per cent of Total	Cumulative Per cent
Under 5 years	202,077	20.5	20.5
5 - 9 years	259,804	26.4	46.9
10 - 14 years	188,980	19.2	66.1
15 - 19 years	64,966	6.6	72.7
20 - 29 years	56,382	5.7	78.4
Over 30 years	133,237	13.5	91.9
Unclassified*	79,118	8.1	100.0
Total	984,564	100.0	100.0

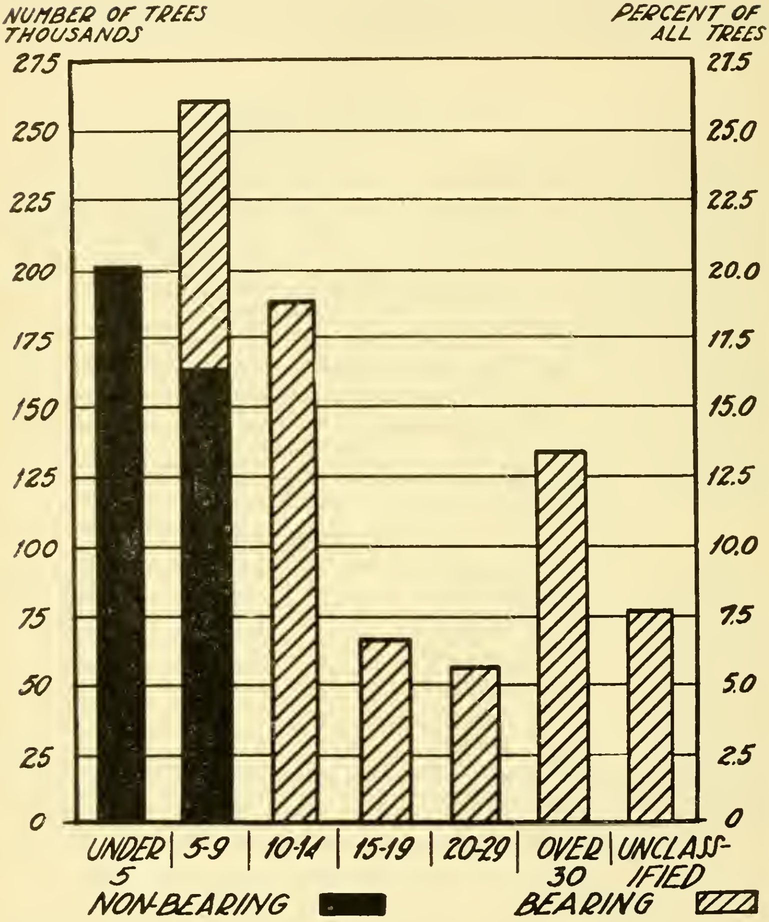
* "Unclassified" means that the age of the trees was not known. Most of these, however, were old trees.

The period of heaviest plantings was between 1915 and 1920. Although there has been a decline of 20 per cent from this high period, new plantings are still being made at the rate of 30,000 to 40,000 trees each year.

Fillers

The number of fillers reported was only 74,000 trees, or about 7 per cent of the total. These were divided equally between bearing and non-bearing, as most of the varieties used for fillers bear at an early age. Fillers are usually cut between the twelfth and fifteenth years, and 95 per cent of those reported are under fifteen years of age. The age grouping is fairly uniform, so that approximately 5,000 trees will be cut each year for the next fifteen years. Several varieties are used as fillers, but about half of those now planted are Wealthy. The McIntosh ranks second in importance, but it is probable that few of the McIntosh fillers will be removed, since already Baldwin and Delicious planted as permanents are being cut instead of McIn-

CHART 3. Age of Trees, 1925



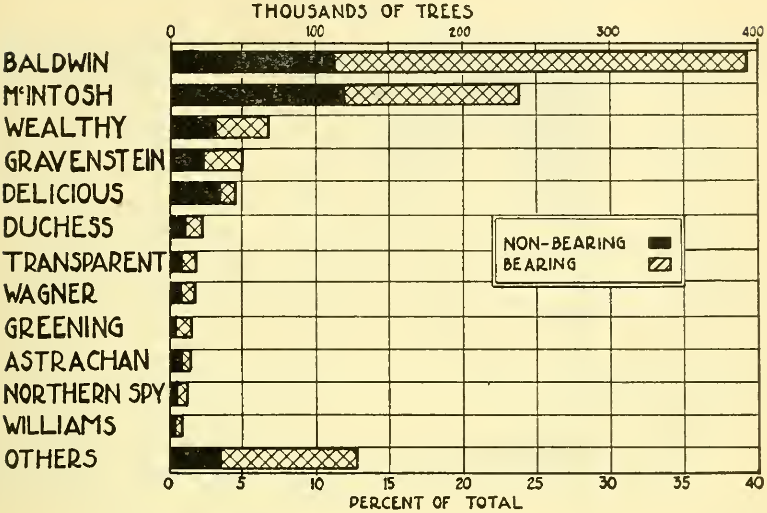
tosh. The Duchess, Wagener and Transparent are all used extensively as fillers and are of about equal importance. Growers expressed considerable dissatisfaction with the filler system and it is not being used on many of the new plantings.

Many growers were unable to state the exact number of fillers, but it is estimated that the figures given are about 75 per cent correct, which would bring the total number of fillers to approximately 100,000 trees.

Principal Varieties

Over 100 varieties were reported by the growers visited, the number of each variety varying from one to several thousand. The number of varieties for which there is a definite market is limited, and there is a strong tendency on the part of the larger growers to limit production to four or five standard varieties. Most of the minor varieties have been planted in small orchards

CHART 4. Non-bearing and Bearing Trees of Leading Varieties, 1925.



for family use or by a few large growers catering to a roadside or other specialized trade.

Baldwin

The Baldwin is the most important commercial variety in Massachusetts, making up 40 per cent of all trees reported. It is found in nine-tenths of the orchards and its continued popularity is indicated by the fact that nearly half of the growers have young trees. Of nearly 400,000 Baldwin trees, over 25 per cent are not yet bearing. The average age, nearly twenty-five years, is

CHART 5. Recent Plantings of Leading Varieties, by Five-Year Periods.

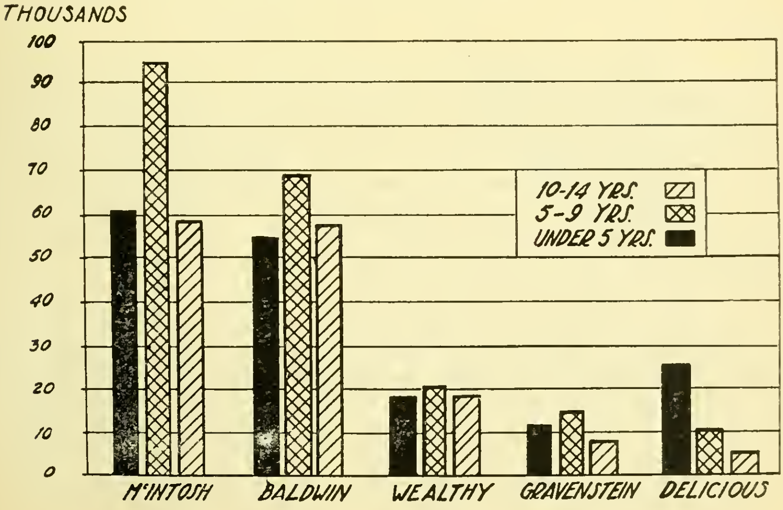
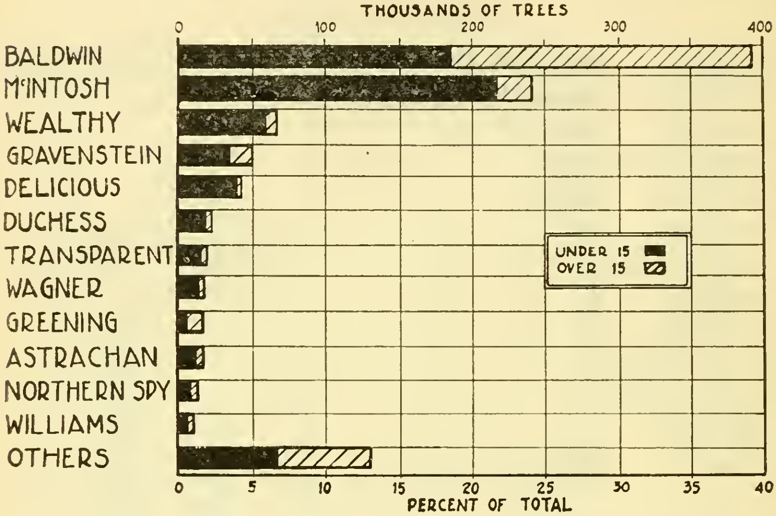


CHART 6. Trees Under and Over Fifteen Years of Age, for Principal Varieties.



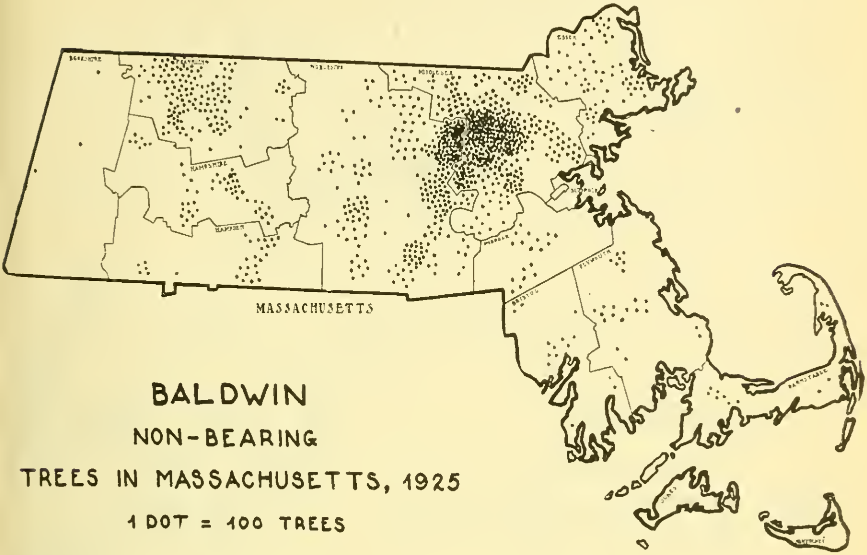
relatively high, one-fourth being over thirty years old. A number of these old trees go out of production each year, but the recent plantings make up for this reduction. Baldwin plantings during the past fifteen years have been almost as heavy as those of McIntosh. Over 50,000 trees have been set during the past five years, and the plantings for the five-year period previous to 1920 were considerably above this figure. Nearly half of the Baldwin trees are under fifteen years of age, and allowing for the loss of old trees, it is reasonable to expect a 50 per cent increase in the crop during the next fifteen years. The popularity of the McIntosh will undoubtedly reduce future plantings of Baldwins. The Baldwin crop in 1924 was over 50 per cent of the entire crop of the State.

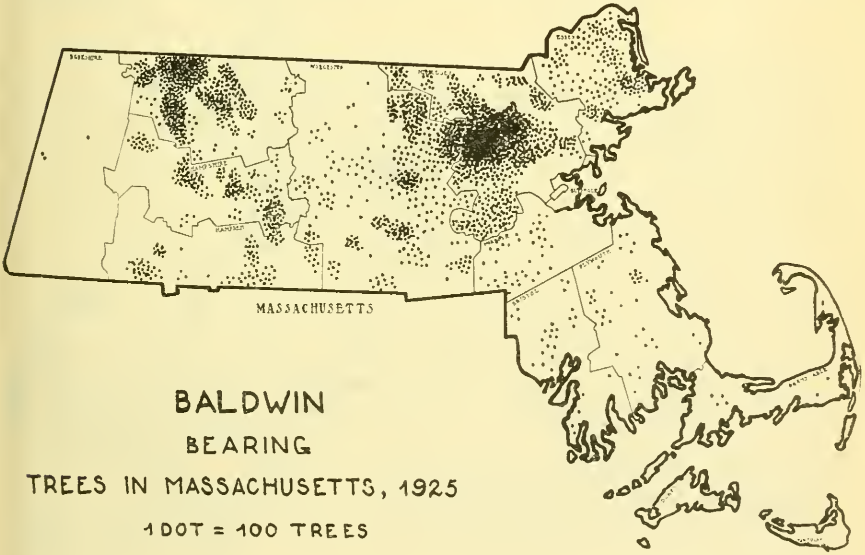
McIntosh

The McIntosh is the second most important variety grown in the State. Nearly 25 per cent of all trees are of this variety and the percentage is increasing each year. Of the 240,000 McIntosh trees reported, about half are not yet in bearing. Over 90 per cent of the McIntosh have been planted during the past fifteen years, which means that only a small number of the trees now bearing have reached full production. The heaviest planting occurred from 1915 to 1920, an average of 18,000 trees being planted per year. The present annual rate of 10,000 trees indicates a 40 per cent decline from that period. The average age of the bearing McIntosh was twelve years in 1925. As these trees mature in the next ten or fifteen years their production will be greatly increased. In addition, about 120,000 young trees will come into full bearing during this period. This estimate includes no new plantings and allows for a loss of 25 per cent of the present young trees. The production of McIntosh in 1924 was slightly over 200,000 bushels, about one-seventh of the total commercial crop. Since the 1924 season was a poor one for McIntosh, this figure is below the average crop.

More grading is done on the McIntosh than on any other variety, approx-

CHART 7. Non-bearing and Bearing Baldwin Trees, 1925.

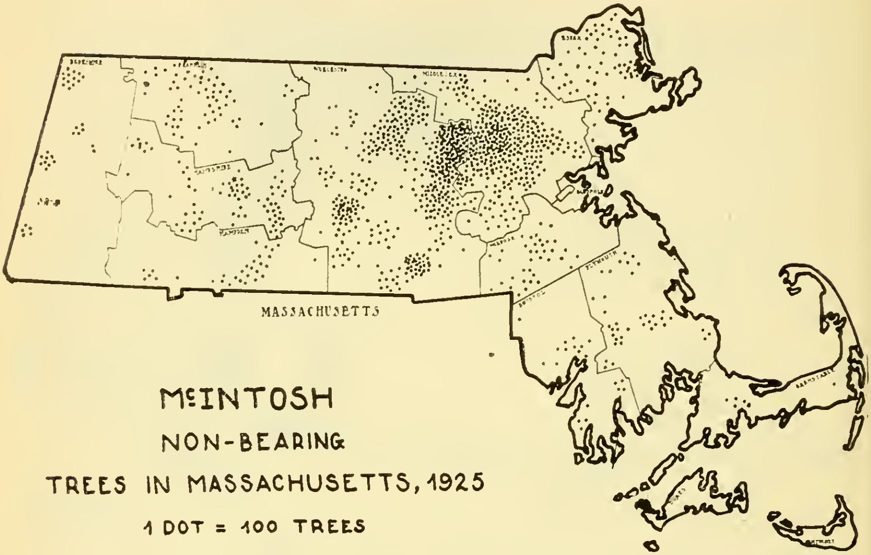

MASSACHUSETTS
BALDWIN
NON-BEARING
TREES IN MASSACHUSETTS, 1925
1 DOT = 100 TREES

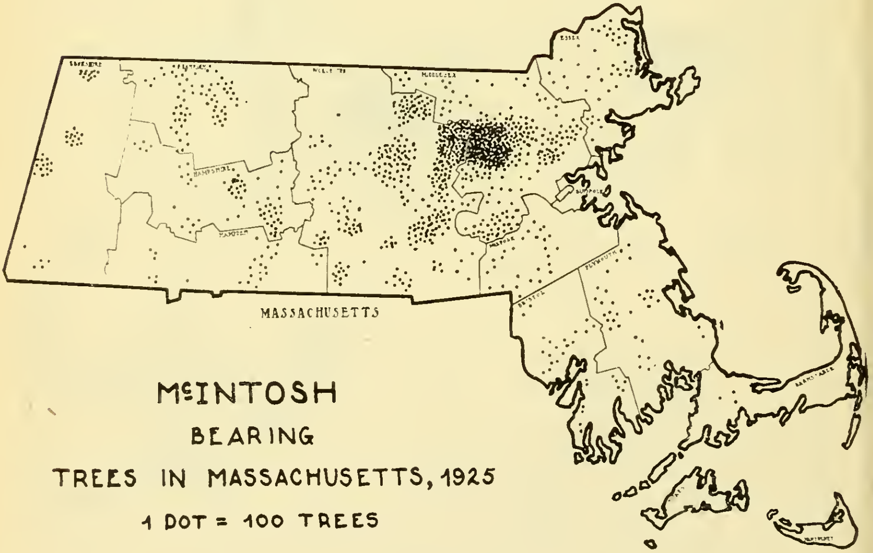

MASSACHUSETTS
BALDWIN
BEARING
TREES IN MASSACHUSETTS, 1925
1 DOT = 100 TREES

imately half of the 1924 crop being graded. Of this amount, 15 per cent were sold as Fancy. About two-thirds were A's and the remainder B's, many growers reporting as much as 75 per cent of their crop as A grade or Fancy. Prices received for McIntosh averaged almost double those for Baldwin, varying with the section of the state, the amount of grading and the care taken in production.

Ten thousand McIntosh trees were reported as fillers, divided equally be-

CHART 8. Non-bearing and Bearing McIntosh Trees, 1925.


MASSACHUSETTS
McINTOSH
NON-BEARING
TREES IN MASSACHUSETTS, 1925
1 DOT = 100 TREES


MASSACHUSETTS
McINTOSH
BEARING
TREES IN MASSACHUSETTS, 1925
1 DOT = 100 TREES

tween bearing and non-bearing. It is probable, as stated above, that many growers who reported McIntosh fillers will not cut them.

Wealthy

The Wealthy is the most important of the minor commercial varieties. Since the Baldwin and McIntosh together make up over two-thirds of the total number of trees, no other single variety appears important when compared with them. There are over 60,000 Wealthy trees in the state, of which nearly half are not yet bearing. The Wealthy is planted primarily as a filler, and nearly 60 per cent of the present number are used for that purpose. Over 80 per cent of the Wealthy plantings are under fifteen years of age, and the production of this variety may be expected to decline very little, even with the removal of fillers. Plantings during each of the five-year periods since 1910 have been about equal and the indications are that the present rate of 3,000 trees per year will continue. Wealthy production amounts to only 5 per cent of the total. About 40 per cent of the Wealthies sold are graded, and 75 per cent of those graded were sold as A's. Disease and insect damage made some difference in this figure during the past season.

Gravenstein

The Gravenstein crop is much larger than the Wealthy crop, although there are fewer trees. Out of nearly 50,000 trees reported, 40 per cent are not yet bearing. The Gravenstein has a higher percentage of non-bearing trees than any other variety except the McIntosh. Plantings during the past five years total over 11,000 trees, a decline of 35 per cent from the preceding five-year period. Two-thirds of the Gravenstein trees are under fifteen years of age, which indicates a substantial increase in production in the future. The total production in 1924 of 115,000 bushels, an average of four bushels per tree, was almost double the Wealthy crop. Two-thirds of the crop was sold ungraded, but of the amount graded, nearly 80 per cent was A grade.

Delicious

The Delicious is a comparative newcomer in Massachusetts, and of the 42,000 trees reported, over three-fourths are not yet bearing. Recent plantings have been very heavy; over 60 per cent of all trees of this variety have been set since 1920. One-fourth of the reporting growers have Delicious trees, usually in small blocks for experimental purposes.

Growers of this variety report sales difficult for the lower grades, but the total volume of production is not sufficient to be a real factor on the market.

Duchess

The Duchess is the favorite of the early varieties, although there are only 20,000 trees, about half of which are not bearing. This variety is principally planted as a filler, 40 per cent of the trees reported being for that purpose. Plantings have fallen off during the past five years, and the present rate of 1,000 per year seems likely to decrease. Most of the Duchess trees are under fifteen years of age, since they are early bearing and short lived. Coming on the market early, production is not an important factor in the general market, except for competition with early Wealthies.

Transparent

The Transparent is another of the early varieties used as a filler. Of the 16,000 Transparent trees reported, three-fourths are bearing. The rate of planting has decreased recently, and many growers express the intention of cutting out these trees. The poor quality of the fruit, its susceptibility to insect injury and small size are some of the reasons advanced for discontinuing the variety.

Wagener

This variety has recently come into favor, particularly in large orchards. Eighty growers reported a total of 15,000 trees in 1925, 60 per cent of which were already bearing. About 50 per cent of the plantings are fillers. Most of the planting has been done during the past ten years, very few trees being more than fifteen years of age. The favor with which this variety is being received by the growers indicates that it will be of more importance in the future.

Greening

The Rhode Island Greening, one of the oldest Massachusetts varieties, is fast passing out. A total of 14,000 trees was reported, of which only 2,000 were non-bearing. Since most of the bearing trees are old, production per tree is high and a total of 26,000 bushels was reported. The poor market for this variety has caused many growers to cut down their trees. The variety is of little commercial importance except in certain sections of the western part of the State.

Astrachan

This variety, formerly a favorite in the farm orchard, is now of little commercial importance. Nearly half of the 13,000 trees reported are non-bearing, and new trees are planted at the rate of nearly 3,000 for each five-year period. The crop is about equal to that of Transparent or Duchess, and comes on the market at about the same time.

Northern Spy

Only 1 per cent of the total number of trees reported were Northern Spy, and plantings are growing less. One-third of the 10,000 trees reported were not bearing, and 70 per cent of the trees are not fifteen years of age. Late bearing and poor market demand account for the lack of popularity of Northern Spy among growers.

Williams

This is one of the older early varieties and is popular in a few sections of the state. Only 7,000 trees were reported, and of this number 2,000 were non-bearing. Recent plantings of over 1,000 trees for each five-year period indicate some increase, which will probably be offset by the cutting of old trees. The production of 17,000 bushels compares favorably with the other early varieties, but is not of sufficient importance to become a factor in the market.

Miscellaneous Varieties

Many other varieties were reported, among them Hubbardston, Wolf River, Grimes Golden, Tolman Sweet, Pippin, etc., none of which is of commercial importance.

Size of Bearing Orchard

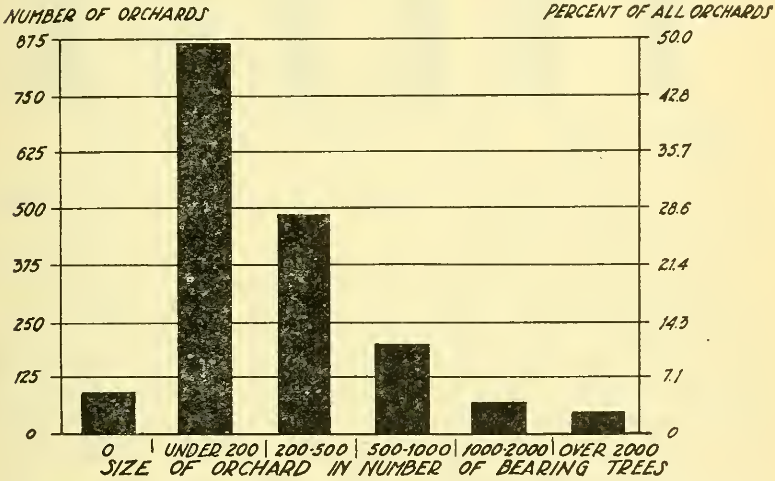
The size of the producing orchard, measured in bearing trees, varies from a few trees to as many as 12,000. The average for all the growers visited is 354 bearing trees. Over half report fewer than 200 bearing trees and the most common size is about 150 trees.

The size of orchard varies with the section of the state. Hampshire County has the highest average with 510 bearing trees. This does not mean that most of the orchards are larger than in other sections, but that there are more large orchards. The most common size is the same for all counties, from 100 to 199 trees. Worcester County ranks second in size with an average of 411 trees, while Hampden County, with 192, is low. Norfolk, Bristol and Plymouth average under 300 trees, indicating few large orchards in those sections.

Ninety-five growers had no bearing trees, but reported young orchards containing nearly one-fourth of the total number of non-bearing trees. This group, comprising only 5 per cent of the growers, averages over 900 young trees per orchard and includes some of the largest single plantings in the state.

Nearly one-fifth of the growers visited own bearing orchards of less than 100 trees. This group of orchards represents blocks of young plantings or old orchards that are well-cared for and commercially important in their section. Many of these growers have maintained a relatively profitable farm orchard for years and are gradually increasing their plantings. This is indicated by the fact that they reported only 3 per cent of the bearing trees, but nearly 16 per cent of the non-bearing trees.

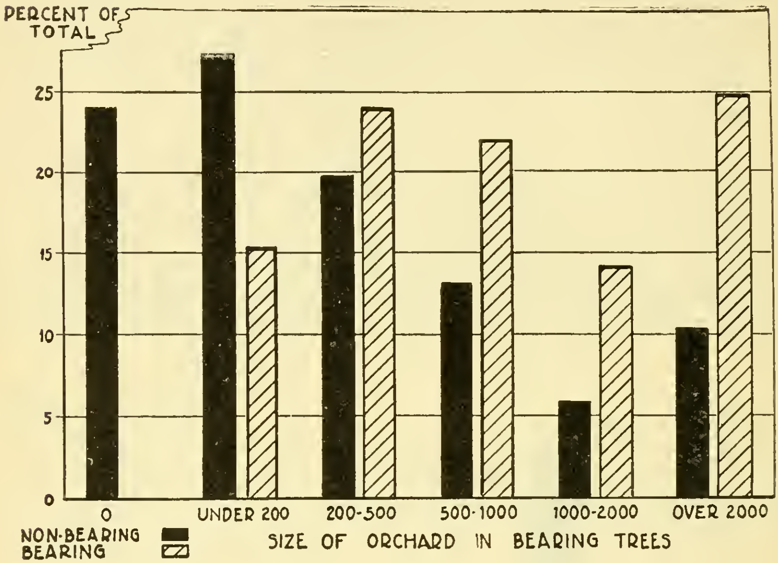
CHART 9. Size of Bearing Orchards, 1925.



Recent plantings have been very heavy on small orchards and nearly half the non-bearing trees were reported by men having fewer than 500 trees. Nearly three-fourths of the trees not bearing have been planted by men with comparatively small bearing orchards, or by men just entering the business.

A comparison of the ages of trees in orchards of different sizes shows that those in orchards of 1,000 or more bearing trees are relatively young. Most of them have been set within the past fifteen years. Old trees are found chiefly in the small orchards and the production per bearing tree averages nearly twice that in the large orchards. For this reason the small orchards of the state produce relatively more of the crop than the large orchards. Orchards of fewer than 200 bearing trees produce one-fourth of the crop, and half the commercial production comes from orchards of fewer than 500 bear-

CHART 10. Percentage of all Bearing and all Non-bearing Trees in Orchards of Different Sizes, 1925.



ing trees. It is evident that the small orchard will be a very important factor in the future market.

Preference for the different varieties varies with the size of orchard. The large orchards have fewer varieties, carefully selected with a view to balanced farm organization and market demand. In general, the percentage of McIntosh increases with the size of orchard and the percentage of Baldwin decreases. The large orchards average one-third Baldwin and over one-half McIntosh. There is a tendency for large growers to plant only Baldwin and McIntosh as permanent varieties, at the rate of two McIntosh to one Baldwin. Most of the bearing Wealthy and Wagener trees are in the large orchards as fillers, as are a large proportion of Duchess trees.

Over two-thirds of the trees in small orchards with many varieties are Baldwin. The McIntosh comprises about one-fourth of the average small orchard, although there are many which contain none of this variety. Most of the bearing Gravenstein are also found in small orchards. The conclusion may be drawn that future increases in McIntosh production will come largely from large orchards, while the greater part of the Baldwin crop will be produced on farms with relatively small orchards.

SOURCES OF INCOME

Most Massachusetts apple growers do not depend solely upon fruit for their income. Specialized fruit farms form only a small percentage of the total number and raise less than 15 per cent of the crop. In many cases fruit growing is a side-line and of secondary importance to the dairy herd. In Middlesex County fruit furnishes 40 per cent of the grower's income; dairying supplies 35 per cent; vegetables, 15 per cent; and poultry, 5 per cent. The remainder comes from a variety of sources. It is significant that in the most highly specialized fruit section of the state dairying is almost as important a source of income as fruit.

In the western part of the state, especially in Franklin County, dairying is more important than fruit, and these two items make up 95 per cent of the income of the average grower. Sales of hay and wages from outside work make up most of the remainder. In Hampshire and Hampden counties dairying is more important than fruit, but poultry, vegetables, hay and other crops furnish a large part of the total farm income.

On most fruit farms there are not more than two principal sources of income. Fruit and dairying are most common in all sections of the state, except in the areas close to Boston. In this section more attention is given to vegetable crops, and fruit and vegetable gardening are the usual combination. This applies to those sections of Essex, Middlesex, Norfolk and Plymouth counties within easy trucking distance of Boston and its suburbs. In other sections, fruit and poultry make a profitable combination on the farm with a moderate size of orchard.

Many specialized growers are combining orchard fruits with small fruits. Raspberries, currants and strawberries are usually planted, and peaches have been successful in a few sections.

ORCHARD PRACTICE

A part of the survey was concerned with the usual orchard practices common among fruit growers in various sections. The results show to what degree scientific methods have been adopted as well as the practices of successful growers.

Pruning

It was found that 81 per cent of the growers prune every year, although this figure is to some extent misleading, since many growers replied that they "prune some every year". Many orchards are practically untouched and from observation it is estimated that not over two-thirds of the trees are thoroughly pruned every season. Fifteen per cent of the growers stated that they prune only occasionally, while 1 per cent do not prune at all.

Cultivation

Over two-thirds of the orchards are in sod and one-third are handled by clean cultivation or with a cover crop. Many growers reported on more than one orchard, so that the actual number of bearing orchards in cultivation is only about 25 per cent of the total. A wide variety of cover crops was reported, buckwheat, rye and millet being common. The usual practice is to cultivate the young orchard, but leave it in sod after it begins to bear.

Fertilizer

Three growers out of four apply fertilizer in some form every year. A wide variety of materials is used, but nitrate of soda is the most common, 60 per cent of the growers reporting its use. Over half of the growers use barnyard manure. Acid phosphate is used by 7 per cent of the growers, while 4 per cent use a complete fertilizer. Only a few users of sulfate of ammonia were found. Other growers reported the use of bone meal, wood ashes, potash, tankage and wool scourings. Three per cent of the growers use no fertilizer.

Spraying

The number of sprays varies widely. The calyx spray is almost universal. Either the dormant or delayed dormant spray is used by 80 per cent of the growers, the pink by 60 per cent, and the pre-pink by only 32 per cent. Nearly one-fourth of the growers reported the use of sprays in addition to those mentioned. The number varied from one to six, used principally for McIntosh. Dusting is not popular, only thirty growers now using it, and several of them expressed the intention of abandoning it in favor of liquid sprays.

Thinning

Twenty-five per cent of the growers do some thinning, but with many it is not a regular practice. McIntosh is the variety usually thinned, but all of the early varieties are thinned to some extent. Only a few growers reported thinning all varieties. The distance varies with the grower, but one apple to a spur and keeping the fruit from touching are the usual practices. A few growers thin to the recommended distance of six to eight inches. The practice is spreading and many growers are convinced of its value, although unable to do very much thinning on account of lack of time or experienced help.

PRODUCTION

A total production of 1,712,000 bushels was reported, and of this amount 88 per cent was sold as marketable fruit. The farm consumption is relatively high, due to the large number of small orchards. A small amount of salable fruit is manufactured on the farms, principally for jellies, apple butter and similar products.

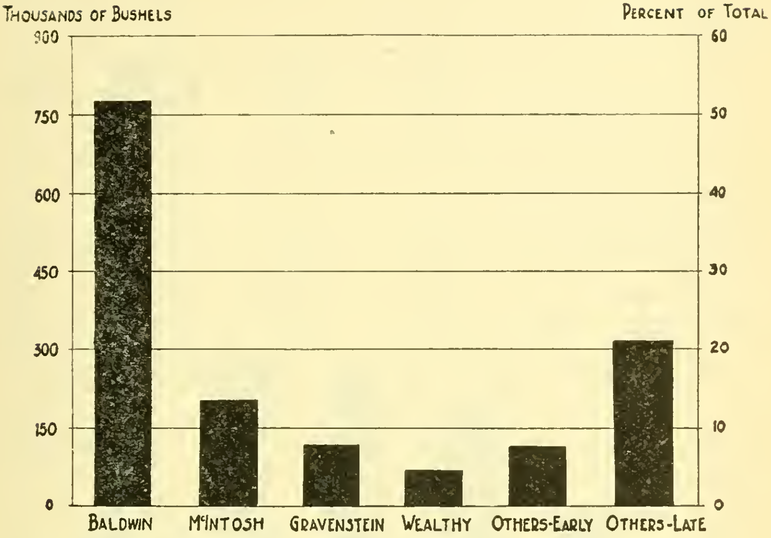
Over 12 per cent of the total production reported was culls or cider apples. In Franklin County 20 per cent of the production was culls, ciders or waste, partly due to poor quality and partly because of the sale of wild apples for cider. In the better commercial sections, the defective and cull fruit averages from 8 to 10 per cent of the total. Two-thirds of the culls are sold for cider, and 13 per cent are made into cider or other apple products on the farm. A few are fed to livestock and apparently about 3 per cent are wasted, most of the waste occurring in the poor fruit sections.

MARKETING

Grades

Grading in some form is practiced by two-thirds of the growers. Most of the grading is done by hand, only 80 graders being reported. The favorite graders are the Pease and Cutler with a few machines of each of a half-dozen other makes. The number of grades varies with the grower, the amount and the quality of the crop, the varieties grown, and the custom of the section. Many growers do not distinguish between sorting and grading, and much of the grading reported means nothing more than the removal of small and defective fruit. Three-fourths of the growers sell only one or two grades of apples. Growers reporting one grade do not sell their defective fruit, using it on the farm; when two grades are sold, one of them is usually culls.

CHART 11. Production of Principal Varieties, 1924.



Only 209 growers reported the sale of more than two grades, while 23 reported as many as four or more grades.

Massachusetts apples are sold in three graded and three ungraded classes. The graded classes are Fancy, A and B. The ungraded include one class from which legal grades have been removed; one from which culls and ciders only have been removed; and one which includes all apples as they come from the tree. The usual grades for the growers reporting three grades are A, B and culls or ungraded. Less than 1 per cent of the growers make a practice of putting up a Fancy grade. There is a widespread belief that too close grading is not profitable, and prices received offer some justification for this belief.

The percentage of each grade varies with the variety.* The following table shows the distribution into market classes of the crop of 1924. It will be noted that in every case the highest proportion of apples was sold as "ungraded, culls and ciders out", and that 65 per cent of all apples were sold ungraded. Sixty-three per cent of all graded fruit was found to be in A grade.

By varieties, it is of interest that Delicious apples show the highest percentage of Fancy, more than 10 per cent being reported in this class, in contrast with less than 3 per cent for all varieties. This is to be accounted for by the fact that the market demand for this variety is almost entirely for the better grades. Northern Spy shows a higher proportion of A grade than any other variety, 36 per cent, and the McIntosh stands second with 30 per cent in this grade. McIntosh likewise has the highest percentage of graded fruit. Only 35 per cent of the Baldwin crop was reported graded. This variety is grown largely in small orchards, where comparatively little grading is done.

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* Summer varieties include Duchess, Transparent, Williams, Astrachan, etc.
Fall varieties include McIntosh, Wealthy, Gravenstein.
Winter varieties include Baldwin, Northern Spy, Delicious, Wagener, Greening, etc.

TABLE 2. Percentages in Grades of Summer, Fall and Winter Apples, 1924

Grade	Summer	Fall	Winter	Total
Graded:				
Fancy	2.9	5.4	1.69	2 76
A	24.5	28.9	19.95	22.6
B	9.95	10.1	9.6	9.8
Total graded	37.35	44.4	31.24	35.16
Ungraded:				
A and B out	1.75	1.17	1.23	1.24
Culls and ciders out	52.0	44.4	44.5	45.0
Tree run	7.5	9.2	20.5	16.9
Other salable*	1.4	.75	2.22	1.78
Total ungraded	62.65	55.52	68.45	64.92

* "Other salable" includes apples used for farm consumption and for farm manufacture, exclusive of culls and ciders. These probably belong largely with ungraded.

Furthermore, the Baldwin commonly produces few apples of the higher grades, making the cost of grading too high for profit.

Methods of Sale

The method of sale varies with the locality. Fifteen different methods were reported, but four are outstanding. The commission man is the most important figure in marketing the crop, and over one-third of all Massachusetts apples are sold through the various commission houses of the state. Country buyers, including peddlers, handle nearly one-fourth of the crop, and in some sections as much as three-fourths. More than 10 per cent is sold outright to wholesalers and an equal amount goes to retail grocers. Direct sales to consumers in one of several ways account for most of the remainder of the crop.

Door to door sales are most common in the Connecticut Valley and the southeastern part of the state, about 20 per cent of all apples in these districts being so distributed, while less than 8 per cent in Middlesex and Worcester counties are sold by this method.

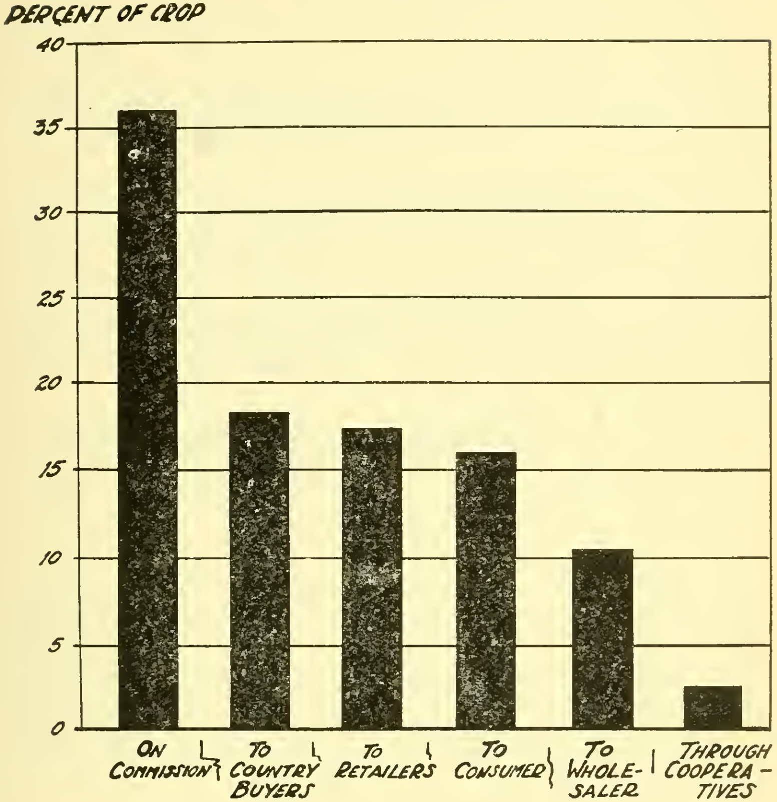
Roadside stands sell about one-fourth of the apples reported in the southeastern part of the state, while but 4 per cent in Middlesex, Worcester and the western counties are sold in this way.

Sales to retailers comprise but 12 per cent of all sales in Middlesex and Worcester counties, although in some other sections retailers receive as high as 34 per cent of all apples.

While sale on commission is the most important method for the state as a whole, its use is by no means uniform. Only 1 per cent in Franklin County are so reported. In the central part of the state where it is used most, an average of 42 per cent of the apples are handled by commission men.

Sales to country buyers, who may be wholesalers, retailers or hucksters, are most common in Franklin County, where they receive 65 per cent of the apples. In the remainder of the state country buyers purchase only 12 per cent of the apples sold. Two per cent of the apples reported were exported, and these mostly on commission. Few exporters buy apples outright.

A comparison of methods of sale and varieties of apples shows that of all apples sold directly to consumers, either at the roadside or from door to door, CHART 12. Methods of Sale Used by Growers, 1924.



6 per cent are summer varieties, 24 per cent, fall; and 70 per cent winter varieties. Of apples sold to retail distributors, 5 per cent are summer, 21 per cent are fall, and 73 per cent winter varieties. Winter apples comprise 80 per cent of wholesalers' purchases; less than 3 per cent are summer apples, and 16 per cent are fall varieties. Sales on commission are made up of 54 per cent winter apples, 38 per cent fall varieties and 8 per cent summer varieties.

Of 1,200,000 bushels on which the methods of sale were reported, 69,000 were summer apples, 326,000 were fall, and 797,000 winter varieties. Table XIV (appendix) shows that there is considerable difference in the methods of selling early and late varieties. Large growers produce most of the summer and fall apples, which are more perishable than the later varieties and must therefore be marketed as quickly as possible. Over 60 per cent of these apples are shipped to the wholesale markets, nearly half of them to commission men.

Country buyers purchase a smaller percentage of early apples than of the late varieties, because they prefer a storable apple of comparatively low grade. Most of the sales to country buyers are Baldwin. A larger proportion of early than of late apples is sold at roadside stands, automobile traffic being heaviest in the late summer and early fall.

PRICES

A study of prices received for apples of different grades shows that graded fruit averages more than 25 cents a bushel above ungraded fruit. Local prices are more valuable to the fruit grower than a general average, and although price information was obtained for all fruit sold, it is not possible to present here all the figures obtained. Two sections, consisting of two towns in Franklin County and three towns in the Nashoba area, have been chosen as typical.

In the Nashoba district apples are commonly sold in boxes and the percentage of graded fruit is higher than in Franklin County, where most apples are sold ungraded and packed in barrels. Sales in the Nashoba area are mostly on commission in Boston, within easy hauling distance. In Franklin County the most common method of sale is to country buyers who come to the orchard, make whatever bargain they can with each grower, and buy the apples at the farm. These differences in method are undoubtedly factors which contribute largely to the differences in price reported from the two sections.

TABLE 3. Average per Bushel by Grades of Leading Varieties, in Two Selected Districts, 1924

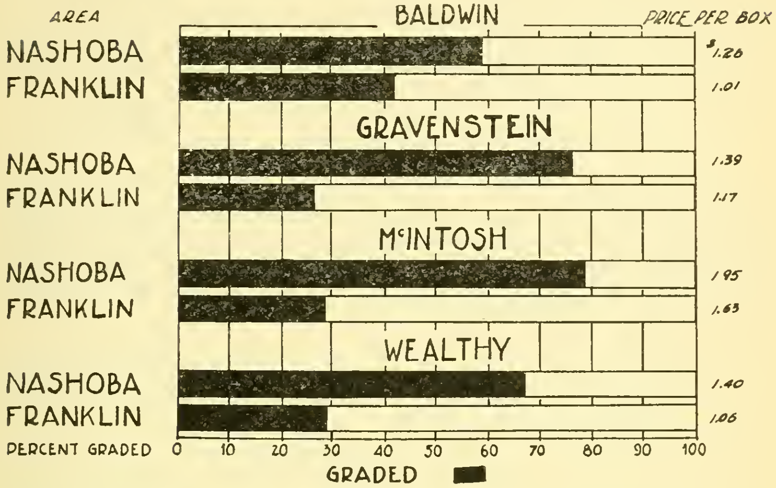
Three Towns in the Nashoba District

Variety	A	B	Ungraded, Culls and Ciders Out	Tree Run	All Grades
Baldwin . .	$1.44	$1.18	$1.02	$1.15	$1.26
McIntosh . .	2.14	1.81	1.58	1.64	1.95
Wealthy . .	1.49	1.41	1.37	1.15	1.40
Two Towns in Franklin County					
Baldwin . .	1.12	.91	1.03	.52	1.01
McIntosh . .	2.04	1.70	1.57	1.45	1.63
Wealthy . .	1.33	1.03	1.34	.88	1.06

The accompanying chart, Chart 13, presents the comparison of the prices and the proportion of graded and ungraded fruit sold of each of the four leading varieties, Baldwin, Gravenstein, McIntosh and Wealthy, for the two sections under consideration. It will be noted that the average prices in the towns of the Nashoba area run uniformly higher than in the towns of Franklin County for similar varieties and grades. (cf. Table 3). These differences are caused by accessibility of market, methods of sale, quality of fruit, and the amount of grading done, but it is obviously difficult to determine which has the greatest effect on price.

Baldwins, of which 59 per cent are graded in the towns of the Nashoba district, returned an average price of $1.26 per bushel. In the two Franklin County towns, with 41 per cent graded, this variety brought $1.01 a bushel. This margin of 25 cents represents the average difference in price for all grades between the two areas.

CHART 13. Amount of Grading and Average Prices Paid to Growers in Two Typical Sections, 1924.



The greatest difference in price between all graded and all ungraded in both districts is for McIntosh, amounting to a little more than 50 cents a bushel. McIntosh prices averaged from 50 per cent to 100 per cent higher than those received for any other commercial variety. The Baldwin prices are lower than those of any other variety, probably because of the quantities available and the relatively low quality. Prices received for Wealthy and Gravenstein apples average above those of most winter varieties.

MARKETS

Massachusetts apples are distributed widely, going by carlots to markets as far west as Chicago and as far south as Washington. From the reports of growers it is estimated that 15 per cent of the Massachusetts crop is sold outside the state, principally in New York.

A large amount of fruit in western Massachusetts is sold to storage companies and other dealers from New York State. The Connecticut Valley furnishes fruit to Hartford, Providence and New Haven. Providence is an important market also for the central and southeastern sections, and prices average higher on Rhode Island markets than on the local markets in those sections.

Boston is the most important Massachusetts market, receiving over one-third of the crop. Worcester and Springfield are important markets in the western part of the state, and are supplied almost entirely from nearby producing areas. Smaller cities, such as Pittsfield, Holyoke, Greenfield, Lowell and Haverhill consume large quantities of apples supplied locally. In some cities large quantities are sold by growers to retailers, while in others sales are almost entirely to wholesalers or on commission. Most of the smaller towns and cities are partly supplied with local fruit through door-to-door sales.

Exports

Only 2 per cent of the crop of 1924 was reported as exported. Most exports are handled on commission, the hazards of the business being so great that in general the dealers do not care to buy outright for export. A few growers have exported considerable portions of their apple crop for a good many years. These men have learned to pack for foreign markets so that comparatively few "slack" packages appear among their shipments.

Storage

Growers report available storage space for 919,000 bushels, but less than 20 per cent of the available space was used in 1924. The farm cellar is the usual place of storage, although more storage buildings are built each year. Many growers with young orchards intend to build or enlarge their storage space as their orchards come into full bearing.

Of the 227,000 bushels stored by farmers in 1924, over 50,000 bushels were placed in city storage warehouses. Boston handles half of the fruit going into city storage, but some storage was reported in Worcester, Springfield, Greenfield, Fall River and Providence.

The late winter varieties, such as Baldwin, make up the largest part of fruit stored on farms. These are usually kept until the holiday season or later. Many growers who supply their local markets from storage holdings, frequently have fruit on hand as late as March or April. However, the bulk of the fruit in farm storage is usually disposed of by January.

More McIntosh are stored each year, and they are held for a longer time than formerly. Most of the storage holdings are sold out by the end of the holiday season.

Transportation

Information on methods of transportation shows that at some point in their distribution 95 per cent of all Massachusetts apples marketed are hauled by motor truck. This may be all the distance to market, or the haul may be completed by rail. The same is true of hauls by wagon, which are confined almost entirely to Franklin County shipments. Over 70 per cent of all Massachusetts apples shipped in carlots during the four years 1920 to 1923 were from this county.

Future of the Industry

The future of the apple growing industry in Massachusetts and its profitableness to the farmer depend upon the amount and quality of future production. With favorable growing conditions, there is no doubt but that production of all of the important commercial varieties will increase each year. Large numbers of trees are just coming into bearing and yields will increase with maturity. Many of the large orchards of the state now bearing will not reach full production for at least ten years, and over 300,000 trees not bearing at present will come into bearing during the period. Barring the possibility of a disastrous winter which may kill the trees, the estimated future production, together with the number of bearing trees for the leading varieties, is indicated in the following table.

TABLE 4. Estimate of Future Production of Four Commercial Varieties of Apples on 1754 Farms in Massachusetts, 1924-1940 (bushels)

Year	BALDWIN		McINTOSH		WEALTHY		GRAVENSTEIN	
	Bearing Trees	Production	Bearing Trees	Production	Bearing Trees	Production	Bearing Trees	Production
1924	280,000	790,000	118,000	205,000	36,000	66,000	28,000	115,000
1930	310,000	950,000	175,000	400,000	38,000	70,000	32,000	140,000
1935	350,000	1,200,000	235,000	700,000	40,000	75,000	35,000	175,000
1940	375,000	1,300,000	250,000	900,000	35,000	70,000	40,000	200,000

TABLE 5. Estimates of Future Commercial Apple Production in Massachusetts (bushels)

Year	1754 FARMS		State Total	Per cent Increase Over 1924
	Four Varieties	Total		
1924	1,200,000	1,500,000	1,750,000	
1930	1,560,000	1,950,000	2,275,000	30
1935	2,150,000	2,730,000	3,185,000	82
1940	2,470,000	3,135,000	3,610,000	107

It is estimated that the total commercial crop of the state will increase at least 100 per cent within fifteen years. The largest part of this increase will be Baldwin and McIntosh, and the latter will undoubtedly show the greatest increase of any variety. In making the above estimates an estimated loss of from 10 to 40 per cent of the trees was deducted, depending upon the variety and age group. The largest deductions were made from the recent plantings, particularly of Baldwin. Allowances were also made for old trees dying out, and for removal of fillers. The estimates for 1935 and 1940 include probable plantings during the next ten years at a continual annual decrease of 10 per cent from the present rate. It is probable that by 1935 plantings will not be sufficient to replace losses of old trees. Annual plantings of at least 30,000 trees are necessary to maintain a million bearing trees.

It is estimated that within ten years 100 of the largest growers of the state will be producing approximately one-half of the crop. On farms of this type a high production per tree and high quality are the rule, and this fact has an important bearing on future estimates of the total crop. Each year will see a larger part of the commercial crop produced by professional fruit growers, in orchards planted during the past ten or fifteen years. Production in the small orchards may be expected to increase on account of recent plantings, but this increase will be partly offset by the dying of old trees which now largely make up this type of orchard. It is probable that the quality of fruit grown in the small orchard will be poorer than that of the large orchard because less care is given to growing, handling and marketing. Most of the small growers do not have the time or equipment to produce and pack the best grades of fruit.

CONCLUSIONS

Securing profitable markets for the probable increase in production is a matter of the utmost importance. One possible outlet is the building up of new markets outside of New England. Many dealers consider New York City as a promising market for McIntosh apples. This variety is coming into favor and there is a growing demand for Massachusetts McIntosh because of the excellent flavor and color. A few growers are now selling in Philadelphia, and further development of this market and others west and south is possible, especially for McIntosh.

A larger quantity of high grade home-grown apples, particularly McIntosh, is reducing the sale of Western apples on local markets. Doubtless this supplanting of Western apples can be carried still further.

According to the Federal Census reports the number of bearing trees in other New England states is declining, and while recent plantings have been heavy, they have not been sufficient to offset the dying of old trees. This decline will probably reduce outside competition on local markets to some extent.

Exporters report a growing demand for American apples of good grade in foreign markets. This market should be carefully guarded from apples of poor quality. Indeed, one method of improving the market generally is by keeping low grade apples off the market entirely. Some growers find it more profitable to make apples of B and lower grades into cider and other by-products than to send them to market. More care in growing, grading and packing fruit will mean profits instead of losses in the future.

A strong organization of fruit growers for the marketing of Massachusetts apples should be able to create or find more profitable markets for good grades of apples. An association of this sort could advertise more successfully than any individual. Advertising offers possibilities in building preferences for Massachusetts fruit in local markets; and it is also possible that through well-planned advertising people may be led to use more apples.

Under present conditions, the careful grower will not plant more trees until the market situation has been adjusted. Growing high grade fruit will remain profitable, although it is possible that the increase in crop will have some effect in lowering prices. Owners of small orchards are urged not to increase their plantings unless they are prepared to give their trees the same attention, and produce fruit of the same quality as that grown in the larger orchards.

The growing demand for McIntosh indicates that there will be little demand for other native varieties reaching the market at the same time. Prices of winter varieties will also be affected by the longer storage of McIntosh.

A study of the apple market, including both domestic and foreign demand, is now under way and will furnish definite information on the marketing situation.

TABLE I. Number of Apple Trees in Massachusetts, by Counties, 1925—Bearing, Non-bearing, Permanent and Filler.

County	TOTAL TREES				NON-BEARING TREES				BEARING TREES			
	Permanent	Filler	Total	Per cent of Total	Permanent	Filler	Total	Per cent of Total	Permanent	Filler	Total	Per cent of Total
Middlesex	334,016	16,061	350,077	35.6	123,984	7,189	131,173	35.7	210,032	8,872	218,904	35.4
Worcester	225,019	23,363	248,382	25.2	98,243	14,368	112,611	30.8	126,776	8,995	135,771	21.9
Franklin	100,198	7,884	108,082	11.1	23,697	4,592	28,289	7.7	76,501	3,292	79,793	12.9
Hampshire	69,377	11,196	80,573	8.2	20,022	2,145	22,167	6.1	49,355	9,051	58,406	9.5
Essex	61,282	5,621	66,903	6.8	17,477	3,181	20,658	5.6	43,805	2,440	46,245	7.8
Hampden	29,944	833	30,777	3.1	7,840	625	8,465	2.3	22,104	208	22,312	3.6
Norfolk	25,663	397	26,060	2.5	9,362	7	9,369	2.5	16,301	390	16,691	2.7
Plymouth	20,703	2,818	23,521	2.4	7,827	1,934	9,761	2.7	12,876	884	13,760	2.2
Bristol	20,779	1,912	22,691	2.3	6,581	750	7,331	2.0	14,198	1,162	15,360	2.5
Berkshire	18,761	3,297	22,058	2.2	12,277	1,217	13,494	3.7	6,484	2,080	8,564	1.4
Barnstable	4,959	481	5,440	.6	2,835	350	3,185	.9	2,124	131	2,255	.4
Total	910,671	73,863	984,564	100.0	330,145	36,358	366,503	100.0	580,556	37,505	618,061	100.0

TABLE II. Age of Apple Trees in Massachusetts, by Counties, 1925

Age	BARNSTABLE		BERKSHIRE		BRISTOL		ESSEX	
	Number of Trees	Per cent of Total	Number of Trees	Per cent of Total	Number of Trees	Per cent of Total	Number of Trees	Per cent of Total
Under 5 years	2,871	52.8	11,864	53.7	5,483	24.1	13,362	20.0
5–9 years	597	11.0	1,630	7.4	4,237	18.7	9,431	14.1
10–14 years	561	10.3	6,333	28.7	8,513	37.6	11,198	16.6
15–19 years	798	14.7	1,883	8.6	3,265	14.4	3,932	5.9
20–29 years	170	3.1	150	.7	517	2.3	2,275	3.4
Over 30 years	260	4.8	198	.9	666	2.9	13,421	20.1
Unclassified	183	3.3	. . . . .	. . . .	10	. . . .	13,284	19.9
Total	5,440	100.0	22,058	100.0	22,691	100.0	66,903	100.0
	FRANKLIN		HAMPDEN		HAMPSHIRE		MIDDLESEX	
Under 5 years	17,505	16.2	5,210	16.9	11,150	13.8	71,103	20.3
5–9 years	17,988	16.6	5,113	16.6	19,855	24.6	97,560	27.9
10–14 years	17,500	16.2	8,227	26.8	19,146	23.8	58,210	16.6
15–19 years	9,934	9.2	3,875	12.6	6,516	8.1	20,664	5.9
20–29 years	14,141	13.1	3,653	11.8	6,808	8.5	20,149	5.8
Over 30 years	17,526	16.2	4,016	13.1	10,500	13.0	59,345	16.9
Unclassified	13,488	12.5	683	2.2	6,598	8.2	23,046	6.6
Total	108,082	100.0	30,777	100.0	80,573	100.0	350,077	100.0
	NORFOLK		PLYMOUTH		WORCESTER		TOTAL	
Under 5 years	3,793	14.6	3,106	13.2	56,630	22.8	202,077	20.5
5–9 years	8,459	32.5	9,054	38.5	85,880	34.6	259,804	26.4
10–14 years	6,320	24.3	9,822	41.8	43,150	17.4	188,980	19.2
15–19 years	1,653	6.3	828	3.5	11,618	4.7	64,966	6.6
20–29 years	831	3.2	512	2.2	7,176	2.9	56,382	5.7
Over 30 years	1,189	4.5	195	.8	25,921	10.4	133,237	13.5
Unclassified	3,815	14.6	4	. . . .	18,007	7.2	79,118	8.0
Total	26,060	100.0	23,521	100.0	248,382	100.0	984,564	100.0

TABLE III. Number of Fillers by Varieties, Bearing and Non-Bearing, 1925

Variety	Non-bearing	Bearing	Total	Per cent of Total
Transparent	1,648	2,836	4,484	6.1
Astrachan	631	453	1,084	1.5
Williams	108	590	698	.9
Duchess	3,898	4,136	8,034	10.9
Wealthy	18.059	16.455	34.514	46.8
McIntosh	5,188	4,432	9,620	13.0
Baldwin	200	1,228	1,428	1.9
Delicious	1,228	45	1,273	1.7
Wagener	4,330	3,095	7,425	10.1
Others	1,068	4,235	5,303	7.1
Total	36,358	37,505	73,863	100.0

TABLE IV. Age of Trees Planted as Fillers, 1925

Age	Non-bearing	Bearing	Total	Per cent of Total
Under 5 years	21,595		21,595	29.2
5–9 years	14,763	11,256	26,019	35.3
10–14 years		22,701	22,701	30.7
15–19 years		3,093	3,093	4.2
20–29 years		391	391	.5
Unclassified		64	64	.1
Total	36,358	37,505	73,863	100.0

TABLE V. Principal Varieties of Apples in Massachusetts—Bearing and Non-Bearing Trees, 1925, with Commercial Production, 1924.

Variety	TOTAL TREES		NON-BEARING TREES		BEARING TREES		COMMERCIAL PRODUCTION	
	Number	Percent of Total	Number	Per cent of Total	Number	Per cent of Total	Bushels	Per cent of Total
Baldwin	387,863	39.4	108,285	29.5	279,578	45.2	788,471	51.5
McIntosh	235,268	24.0	116,844	31.9	118,424	19.2	205,116	13.4
Wealthy	65,857	6.7	29,415	8.0	36,442	5.9	66,284	4.3
Gravenstein	49,424	5.1	20,839	5.7	28,585	4.7	114,786	7.5
Delicious	42,055	4.3	32,685	8.9	9,370	1.5	12,888	.8
Duchess	20,331	2.1	9,046	2.5	11,285	1.8	21,114	1.4
Transparent	16,252	1.6	6,743	1.8	9,509	1.5	20,461	1.3
Wagener	15,472	1.5	5,751	1.6	9,721	1.6	*	*
Greening	13,997	1.4	2,116	.6	11,881	1.9	26,079	1.7
Astrachan	13,545	1.3	6.089	1.6	7.456	1.2	22,247	1.5
Northern Spy	10,919	1.1	3,166	.9	7.753	1.3	13,565	.9
Williams	7,406	.7	2,249	.6	5,157	.8	17,370	1.1
Others	106,175	10.8	23,275	6.4	82,900	13.4	223,031	14.6
Total	984,564	100.0	366.503	100.0	618.061	100.0	1,531,412	100.0

*Production included in "Others".

TABLE VI. Age of Trees of Leading Varieties of Apples in Massachusetts, 1925

Age	TOTAL TREES		BALDWIN		McINTOSH		WEALTHY		GRAVENSTEIN		OTHERS	
	Number of Trees	Per cent of Total	Number of Trees	Per cent of Total	Number of Trees	Per cent of Total	Number of Trees	Per cent of Total	Number of Trees	Per cent of Total	Number of Trees	Per cent of Total
Under 5 years	202,077	20.5	55,062	14.1	60,950	25.2	18,289	27.8	11,056	22.4	56,720	23.0
5–9 years	259,804	26.4	69,785	17.9	95,156	40.9	20,135	30.6	14,714	29.4	60,014	24.4
10–14 years	188,980	19.2	58,064	15.0	58.759	24.8	18,452	28.0	8,113	16.5	45,592	18.5
15–19 years	64,966	6.6	30,521	7.8	11,415	5.0	6,007	9.1	3,396	7.0	13,627	5.5
20–29 years	56,382	5.7	34,641	8.9	4,323	1.9	1,839	2.8	4,306	8.8	11,273	4.6
Over 30 years	133,237	13.5	103,475	26.6	1,588	.7	419	.6	4,759	9.7	22,996	9.3
Unclassified	79,118	7.8	36,315	8.9	3,077	1.4	716	1.0	3,080	6.2	35,930	14.6
Total	984,564	99.7	387,863	99.2	235,268	99.9	65,857	99.9	49,424	100.0	246,152	99.9

TABLE VII. Age of Trees of Less Important Varieties* of Apples in Massachusetts, 1925

AGE	DELICIOUS		DUCHESS		TRANSPARENT		WAGENER		GREENING		ASTRACHAN		NORTHERN SPY		WILLIAMS		OTHERS	
	Number of Trees	Per cent of Total	Number of Trees	Per cent of Total	Number of Trees	Per cent of Total	Number of Trees	Per cent of Total	Number of Trees	Per cent of Total	Number of Trees	Per cent of Total	Number of Trees	Per cent of Total	Number of Trees	Per cent of Total	Number of Trees	Per cent of Total
Under 5 years	25,065	59.6	5,473	26.9	3,986	24.5	1,233	8.0	880	6.3	3,344	24.7	1,211	11.1	1,489	20.1	14,039	13.2
5–9 years	10,925	26.0	6,759	33.2	6,084	37.4	7,606	49.3	1,439	10.3	4,669	34.5	2,846	26.1	1,640	22.1	18,046	17.0
10–14 years	4,797	11.4	5,643	27.8	4,012	24.7	4,906	31.7	2,493	17.8	1,990	14.7	3,427	31.4	1,370	18.5	16,954	16.0
15–19 years	778	1.9	1,336	6.6	840	5.2	643	4.1	688	4.9	828	6.1	975	8.9	672	9.1	6,867	6.5
20–29 years	229	.5	486	2.4	525	3.2	952	6.1	1,341	9.6	755	5.6	350	3.2	445	6.0	6,190	5.8
Over 30 years	144	.3	325	1.6	520	3.2	32	.2	5,804	41.5	1,150	8.5	1,524	14.0	1,367	18.5	12,130	11.4
Unclassified	117	.3	309	1.5	285	1.8	100	.6	1,352	9.6	809	5.9	586	5.3	423	5.7	31,949	30.1
Total	42,055	100.0	20,331	100.0	16,252	100.0	15,472	100.0	13,997	100.0	13,545	100.0	10,919	100.0	7,406	100.0	106,175	100.0

*Included in "Others" in Table VI

TABLE VIII. Average Number of Trees in Bearing Orchards of Different Sizes, 1925

Size of Orchard in Bearing Trees	Bearing Trees	Non-Bearing Trees	Total Trees per Orchard	Per cent Bearing
0	. . . .	925	925	. . . .
1–199	109	116	225	48.5
200–499	310	151	461	67.2
500–999	672	238	910	73.8
1000–1999	1,315	318	1,633	80.5
Over 2000	3,490	856	4,346	80.3
Average—all orchards	354	209	563	63.0

TABLE IX. Percentages of Trees and Production in Orchards of Different Sizes, 1925

Size of Orchard in Bearing Trees	Per cent of Growers	Per cent of Non-Bearing Trees	Per cent of Bearing Trees	Per cent of All Trees	Per cent of 1924 Production
0	5.4	23.9	. . . .	8.9	. . . .
1–199	49.4	27.3	15.3	19.8	19.2
200–499	27.4	19.7	23.9	22.4	28.2
500–999	11.5	13.1	21.9	18.6	23.4
1000–1999	3.8	5.8	14.2	11.0	13.0
Over 2000	2.5	10.2	24.7	19.3	16.2
Total	100.0	100.0	100.0	100.0	100.0

TABLE X. Commercial Production of Apples by Varieties, Graded and Ungraded, 1924 (bushels)

Variety	Graded	Ungraded	Per cent Graded	Total
Baldwin	285,038	503,433	36.4	788,471
McIntosh	107,439	97,677	52.2	205,116
Wealthy	28,001	38,283	42.4	66,284
Gravenstein	44,467	70,319	38.7	114,786
Delicious	5,125	7,763	39.7	12,888
Duchess	8,227	12,887	38.9	21,114
Transparent	7,808	12,653	38.2	20,461
Greening	7,970	18,109	30.5	26,079
Astrachan	7,579	14,668	34.1	22,247
Northern Spy	6,380	7,185	47.0	13,565
Williams	8,078	9,292	46.5	17.370
Others	41,778	181,253	18.7	223,031
Total Commercial Production	557,890	973,522	36.4	1,531,412
Total Culls, Ciders and Waste				181,328
Total Production . . .				1,712,740

TABLE XI. Commercial Production of Leading Varieties of Apples, by Counties, 1924 (bushels)

Variety	Barnstable	Berkshire	Bristol	Essex	Franklin	Hampden	Hampshire	Middlesex	Norfolk	Plymouth	Worcester	Total
Baldwin	425	562	3,672	44,136	159,936	38,956	73,116	317,067	9,196	4,527	136,878	788,471
McIntosh	175	5,025	4,363	5,641	11,196	8,471	15,319	78,158	3,868	2,380	70,520	205,116
Wealthy	115	1,050	1,111	2,195	2,490	3,759	8,149	29,783	1,236	1,666	14,730	66,284
Gravenstein	135	...	770	3,623	1,623	1,637	1,877	84,521	2,060	461	18,079	114,786
Delicious	50	...	2,346	270	690	16	534	2,139	1,855	608	4,380	12,888
Duchess	8	600	729	1,304	1,224	2,010	2,469	9,718	256	360	2,436	21,114
Transparent	62	...	1,266	499	183	215	380	14,620	261	422	2,553	20,461
Greening	45	6	185	327	9,195	3,247	5,277	3,206	1,137	127	3,327	26,079
Astrachan	90	50	1,140	1,489	843	361	1,238	14,306	178	454	2,098	22,247
Northern Spy	70	9	79	682	1,410	3,027	2,341	3,381	339	255	1,972	13,565
Williams	20	...	635	634	72	1	109	13,388	113	66	2,332	17,370
Others	946	2,900	5,708	23,410	7,008	12,016	30,014	69,162	9,700	2,763	59,404	223,031
Total	2,141	10,202	22,004	84,210	195,870	73,716	140,823	639,449	30,199	14,089	318,709	1,531,412

TABLE XII. Total Production of Leading Varieties of Apples in Massachusetts, by Grades, 1924

Grades	EARLY SUMMER*		WEALTHY		GRAVENSTEIN		McINTOSH		BALDWIN		OTHERS		TOTAL	
	Bushels	Per cent of Total	Bushels	Per cent of Total	Bushels	Per cent of Total	Bushels	Per cent of Total	Bushels	Per cent of Total	Bushels	Per cent of Total	Bushels	Per cent of Total
Commercial:														
Fancy	2,475	2.9	2,934	4.4	2,061	1.8	17,373	8.5	12,642	1.6	4,876	1.8	42,361	2.8
A	20,971	24.5	18,063	27.2	32,841	28.6	62,322	30.4	172,315	21.8	40,207	14.8	346,719	22.6
B	8,522	9.9	6,538	9.9	8,542	7.4	24,593	12.0	89,557	11.4	11,982	4.4	149,734	9.8
Ungraded, A and B out	1,502	1.8	466	.7	1,023	.9	3,151	1.5	10.524	1.3	2,410	.9	19,076	1.2
Ungraded, culls out	44,491	52.0	31,636	47.7	61,691	53.8	79,653	38.9	357,548	45.3	112,348	41.5	687,367	44.9
Tree Run	6,404	7.5	6,410	9.7	7,768	6.8	16,256	7.9	129,193	16.4	93,842	34.6	259,873	17.0
Farm Manufacture	71	. . .	4	. . .	38	. . .	36	. . .	1,215	.2	631	.2	1,995	.1
Farm Consumption	1,158	1.4	233	.4	822	.7	1,732	.8	15,477	2.0	4,865	1.8	24,287	1.6
Total Commercial Production	85,594	100.0	66,284	100.0	114,786	100.0	205,116	100.0	788,471	100.0	271,161	100.0	1,531,412	100.0
Culls, Ciders and Waste														
Culls and Ciders Sold	491		25		160		242		6,592		119,334		126,844	
Culls and Ciders Manufactured	25		. . .		60		65		2,411		22,650		25,211	
Culls and Ciders Consumed on Farm	1,056		27		150		12		7,861		14,778		23,884	
Shrinkage and waste	820		72		15		171		1,847		2,464		5,389	
Total Culls, Ciders and Waste**	2,392		124		385		490		18,711		159,226		181,328	
Total Production	87,986		66,408		115,171		205,606		807,182		278,560		1,712,740	

*Includes Transparent, Astrachan, Williams, Duchess, etc.

**Where only one figure for ciders was given, all varieties were included under "Others."

Table XIII. Percentages of Apples Sold by Different Methods, by Counties, 1924

Method of Sale	Barnstable	Berkshire	Bristol	Essex	Franklin	Hampden	Hampshire	Middlesex	Norfolk	Plymouth	Worcester	Total
Door to Door	28.5	6.1	12.3	9.6	8.2	17.0	30.3	6.3	25.8	18.3	9.3	10.3
Roadside	24.9	14.3	23.4	5.3	2.4	1.0	1.3	3.6	13.5	45.0	1.9	4.3
To Peddler	11.4		4.4	15.7	4.7	13.8	14.0	4.3	6.5		1.6	5.6
To Retailer	29.4	12.3	34.0	15.2	5.2	24.0	6.3	7.5	31.4	28.0	15.8	11.8
To Wholesaler		1.7	11.0	19.2	9.0	4.6	17.5	7.7	8.7		16.0	10.8
To Country Buyer			1.2	27.4	65.0	11.1	16.6	17.5	5.0	2.1	18.6	18.1
On Commission	5.7	65.5	13.8	6.7	.7	27.2	10.0	47.0	8.9		29.2	33.9
Farmers' Market					.2		1.0	.7		6.4	.5	.5
Co-operatively						.9	2.4	2.1			5.6	2.3
For Export				.7	1.6		.1	3.0			1.5	2.0

Table XIV. Percentage of Summer, Fall and Winter Apples Sold by Different Methods, 1924

Method	Summer	Fall	Winter	Total
Direct to Consumer	6.2	6.5	12.3	10.3
Roadside Market	8.8	6.4	3.0	4.3
Peddler	4.3	3.5	6.5	5.6
Retailer	11.5	10.0	12.5	11.8
City Wholesaler	6.1	7.4	12.6	10.8
Country Buyer	8.9	11.2	21.7	18.1
On Commission	51.0	46.5	27.2	34.0
Farmers' Market	1.0	.8	.4	.5
Co-operatively	.1	4.7	1.5	2.3
For Export	1.7	2.4	2.0	2.1

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BULLETIN No. 229 APRIL, 1926

SOIL REACTION AND BLACK ROOT-ROT OF TOBACCO

By P. J. ANDERSON, A. VINCENT OSMUN and W. L. DORAN

Black root-rot is a serious menace to successful tobacco production in the Connecticut Valley. The causal fungus is found in most tobacco soils of the Valley. Low temperature during the growing season, and high lime conditions in the soil, both stimulate its activity. Injury may vary all the way from complete destruction of the crop, on heavily limed soils in cold growing seasons, to a damage scarcely noticeable. Not only does the root-rot depress yield, but it may injure quality of leaf as well.

There are but two known methods of combating the disease: first, through control of lime conditions in the soil; and secondly, through the use of root-rot resistant strains of tobacco. This bulletin reports results of research on the former.

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SOIL REACTION AND
BLACK ROOT-ROT OF TOBACCO

By P. J. ANDERSON, A. VINCENT OSMUN and W. L. DORAN[1]

Black root-rot probably causes greater loss to the tobacco growers of the United States than does any other disease. In the Connecticut Valley, according to published records, it has caused varying amounts of damage since 1906. It was probably prevalent long before that time, but had escaped attention. Within the last decade its ravages have been reduced considerably through improved cultural practices, based on a better knowledge of the effect of certain environmental factors on the virulence of the disease. Nevertheless it still takes its annual toll from the crop and, as one of the causes of "tobacco sick" soils, is an important factor in tobacco production in Massachusetts.

Symptoms of Black Root-Rot

The first symptom of the disease which the grower notices in the field is that the tobacco doesn't grow. The plants remain stunted, with narrow, thick, tough leaves and either a starved yellow color or, where the nitrogen supply is high, a very dark green color commonly called "black" by the tobacco man. On hot days the leaves wilt and "flag" more quickly than healthy tobacco plants. The dwarfed plants "top out" prematurely. Only rarely is a field equally affected in all parts. Usually there are "patches" from a square rod to several acres in extent, where the tobacco is short while in other parts of the field the growth is normal. In the diseased "patches" the plants are frequently very uneven in growth.

From the above ground symptoms, however, it is not possible for even an expert to be sure that this is black root-rot. Other troubles such as brown root-rot, lack of fertilizer, or water-logged soil may produce the same appearance. One must dig the plants and wash the soil from the roots to see the lesions which are the unmistakable signs of black root-rot. Normal young roots are white, but on a diseased plant many are black (brown at first), either throughout their length or frequently only in segments, with other segments appearing normal. Most of the ends of the small roots are black, indicating that in digging the plant, the root broke at this point and the decayed end was left in the soil. The tissue of the smaller roots is rotted through, but on the large roots there occur enlarged, rough, scurfy lesions which may or may not kill the interior tissues. Frequently the tap root is entirely rotted off at the bottom and there is an increased number of laterals. This results in a brush-work of intermingled brown, black and white small roots just above the blackened end of the main root. The brown lesions are caused by the same organism (*Thielavia basicola* Zopf)[2] which later produces the black ones, the color depending on the age of the lesion. The character which distinguishes this disease from all other tobacco diseases is the coal black color of parts of the roots. The reduced root system is unable to secure sufficient water and soil nutrients for normal growth of the above ground parts of the plant, hence the dwarfed slow growth and "flagging" on hot days.

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[1] During the first year of this investigation the work was conducted by G. H. Chapman, formerly research professor of Botany at this Station.

[2] McCormick (Conn. Agr. Exp. Sta. Bul. 269, 1925) considers this *Thielaviopsis basicola* (Berk.) Ferraris.

Black root-rot may also occur in the seed-beds, where it exhibits the same symptoms, viz., slow growth, yellow or "black" color of leaves, "flagging," and black rotted roots. Many of the plants also die. The beds look very uneven.

PREVIOUS INVESTIGATIONS

In the first experiment station publication which recorded and described the disease in the Connecticut Valley, Jenkins and Clinton (5:7)[3] stated:

"It is not definitely known whether an acid, alkaline or a neutral soil is best adapted to the growth of the fungus, which we know can grow in the soil itself apart from the tobacco root, but it is reasonable to suppose that this factor may have its influence."

Later (5:8):

"One of the growers whose fields suffered severely was inclined to lay it to the excessive use year after year of potash fertilizers, which gradually accumulated in the soil, and especially to the use of the carbonate of potash."

The first, and up to the present date the most important, contribution on the relation of soil reaction to root-rot was a brief circular by Briggs (1) describing results of experiments in Connecticut in 1907. His conclusions are best summarized in the following statements which we quote:

"The results of the writer's investigations thus far indicate that the tobacco is much more severely injured by the fungus on fields where the soil has been made alkaline by the long-continued use of large amounts of lime, ashes and fertilizers containing carbonate of potash."

"In all cases it was found that the plots on which carbonate of potash was used gave the smallest plants and the lowest yields. The use of lime with the carbonate of potash still further diminished the yield. The use of carbonate of potash and lime with cottonseed meal and ground fish gave a yield of but 900 pounds per acre. This yield was 200 pounds less to the acre than when no fertilizer was used and was only a little more than half the yield obtained from some of the other plots."

In pot experiments he found that:

"In soils free from root-rot, the use of 1 per cent of lime gave a better growth of tobacco than where no lime was used. This shows that the lime does not injure the tobacco directly . . . . The use of hydro-chloric acid, on the other hand, increased the yield by about 10 per cent although this acid carries no plant food . . . . The root systems of the plants in all the pots to which lime or carbonate of potash was added were badly diseased . . . . The roots of the plants grown in acid-treated soil were perfectly clean and white, and entirely free from the fungus."

All of Briggs' experiments were with naturally infested soils from fields where the soil acidity had been greatly reduced by use of alkaline fertilizers and lime. The reaction of the soil was not determined either before or after the treatments which he applied.

Johnson and Hartman (7:53-60) determined the influence of soil reaction on root-rot by growing plants in pots after adding graduated quantities of calcium hydroxide to a naturally very acid soil inoculated with macerated diseased roots. Acidity was determined in terms of lime requirement according to the Truog method. From these experiments they concluded that:

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[3] Numbers in parenthesis refer to bibliography at the end of this bulletin. Numbers after the colon give the page on which statement referred to may be found.

" . . . . the highest acidity practically eliminated damage from root-rot, but that heavy infection still occurred in fairly acid soil."

When they inoculated all the soils heavily with spores of the fungus *just before planting*, they found that:

"A heavy infestation apparently reduced the efficacy of the acid soils to nothing, at least in the presence of a susceptible variety. The disease appeared, in fact, more virulent in the most acid soil."

This last experiment indicates that the effect of the acid soil is not to increase the resistance of the plant but to retard the development of the fungus.

They also tested in the field the effect of application of acid fertilizers and concluded that:

"For Wisconsin conditions . . . . application of acid fertilizers to soil, alkaline or neutral in reaction, will not reduce infection by *T. basicola*."

Chapman (2) in connection with an investigation of "tobacco sick" soils of Massachusetts made 300 determinations of the lime requirement of tobacco soils and correlated them roughly with the condition of the crop and prevalence of root-rot. He concludes (2:38) that:

"Soils with a lime requirement up to 3000 pounds CaO per acre are not producing good crops as a rule and are comparatively free from root-rots. Those with a lime requirement of from 3000 to 8000 pounds CaO per acre are in good tobacco condition; but in this group, pathogenic fungi are abundant in the soil, and the plants during certain seasons, are very liable to suffer from root-rots caused by some of these fungi. Soils with a lime requirement of 8000 pounds CaO up are usually comparatively free from such fungi, and even in unfavorable seasons, little disease is found."

He explains the relative freedom from root-rot of the soils which show the lowest lime requirement by assuming that these soils are too alkaline for the development of the fungus. His results on this point are at variance with those of Johnson and Hartman. The poor yield is attributed to the unfavorable effect of a too alkaline soil on the tobacco plant.

Chapman questioned the lime requirement method as a means of measuring the acidity of the soils.

Need of Further Investigation

We may summarize the results of all the investigations recorded up to the present: A soil made less acid by the use of lime, carbonate of potash, or ashes favors the development of black root-rot. When, however, the acidity is increased, there is a corresponding reduction in amount of root-rot injury until a point is reached where it is negligible. In regard to the particular degree of acidity which must be attained to escape root-rot and, in general, the correlation of reaction and infection throughout the soil range, Briggs gives no information while Johnson and Hartman and Chapman had contradictory results. In view of this situation and the fact that it is now commonly accepted that the development of fungi is proportionate to *intensity* of acidity as measured by the hydrogen ion concentration method, rather than the *amount* of acidity, as measured by the lime requirement method, there seemed to be need for further experimentation.

Two related problems concerned (1) the effect of lime on tobacco in the absence of root-rot and (2) the effect of the timothy cover crop.

In regard to the first, it is safe to assume that the growers considered lime beneficial, else it would not have come into such general use. Briggs found that 1 per cent of lime in disease-free soil increased growth. Hartwell and Damon (3:437) include tobacco among the lime loving plants. McCall (9) reports that, on heavy loam soil in Maryland, lime increased the yield of tobacco, but that direct applications of lime tended to lower the quality of the leaf. Hutcheson and Berger (4:7) found that, in Virginia, lime at first gave a larger yield but the tobacco was coarse and "bony." In the later years of the experiments, however, they found the tobacco reduced both in quantity and quality by lime. It is quite possible that in this case the later effects were due to root-rot rather than to the direct effect of lime. This is true in other similar experiments where the first effects were good but in later years there was a reduction. Since in most cases root-rot is not mentioned, one cannot be sure whether the experimenter was measuring the effect of the lime or of root-rot. This difficulty renders worthless most of the literature on the effect of lime on tobacco.

During the last decade, the use of timothy as a cover crop has come into considerable favor with tobacco growers of the Connecticut Valley. It reduces washing and blowing of the light soils during the long period between tobacco crops and also adds considerable humus to the soil. Some growers also have the impression that it reduces black root-rot by neutralizing in some way the ill effect of lime. When this experiment was begun there were no published records of experiments to determine the effect of its use on the succeeding crops of tobacco. It became desirable, therefore, to test by accurate experiments its immediate and cumulative effects.

THE FIVE-YEAR EXPERIMENT

In 1921 a series of experiments was, therefore, started for the purpose of answering these three questions:

1. What effect does application of lime have on growth of tobacco in the absence of root-rot?
2. What is the relation between severity of infection and acidity as measured by hydrogen ion concentration?[4]
3. What is the effect of a timothy cover crop on the yield and quality of tobacco and on the severity of root-rot?

During the last five seasons Havana tobacco has been grown continuously on a field of 1.2 acres on the experiment station farm where no tobacco has been previously raised for at least 8 years. The soil is apparently of the Gloucester series. The field was divided into 24 plots of 1-20 acre each according to the diagram presented in figure I. It will be noted from this diagram that limed strips of plots alternated with unlimed strips in one direction; while at right angles, there were duplicate strips of plots (1) without cover crop (2) with timothy cover crop and (3) with clover cover crop.[5] One-half of the field was inoculated while the duplicate half was not inoculated. All cultivation was in the direction of the cover crop strips, thus avoiding as far as possible carrying the fungus to the uninoculated half.

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[4] In measuring reaction in terms of hydrogen ion concentration method, a neutral soil or other substance is designated by the number pH 7, acid substances by the numbers below 7, alkaline substances by those above 7 up to 14. Thus a soil designated by 6 is slightly acid; 5, much more so; 4, more than 5; etc. We are not concerned here with the alkaline end of the scale since all our tobacco soils are naturally acid, and fall within the range from 4 to 7. Even when a large amount of lime is applied, they do not remain above 7 for any considerable time. The degrees of acidity are usually written pH 5, pH 4.5, etc.

The limed plots were treated year by year as follows:

1921, ground limestone,		4000 lbs. per acre
1922, precipitated lime	(51 per cent CaO),	2000 " " "
1923, agricultural lime	(60 " " CaO),	4000 " " "
1924, no lime		
1925, no lime		

The fertilizers applied each year just before setting the plants are described in the following table.

Fertilizers Used—Pounds per Acre

Material	1921	1922	1923	1924	1925
Cottonseed Meal	1200	1200	1481	1270	828
Ammonium Sulfate	120	120	62	90	100
Dry Ground Fish	180	180	247	195	200
Acid Phosphate	160	160	......	....	....
Precipitated Bone	120	120	432	276	....
H. G. Sulfate of Potash	240	240	278	252	280
Ammo-Phos	....	....	....	....	234
Total rate per acre	2020	2020*	2500†	2083‡	1642‡

* Plus a quickly available side dressing at the second hoeing.
† Plus 250 lbs. nitrate of soda per acre applied in July.
‡ Equivalent to 3000 lbs. per acre of a 5-4-5 fertilizer.

That half of the field which was inoculated (see Figure I) was first inoculated in 1921 by setting in it diseased plants taken from a badly infested seed bed. In order to secure heavier infection on the inoculated half, a handful of soil from a heavily infested greenhouse bed was placed in the furrow where each plant was set in 1922. The inoculated half of the field was again inoculated just before setting the plants in 1923, when two cartloads of heavily infested soil from a greenhouse bed were scattered broadcast over it and harrowed in.

Timothy and clover cover crops were sown after harvesting the tobacco in 1921, 1922, and 1923. None were sown in 1924.

Soil samples for pH determination were taken from all plots each year, and the hydrogen ion concentrations which were determined are recorded in Table I.[6] These soil samples were taken before the ground was broken in

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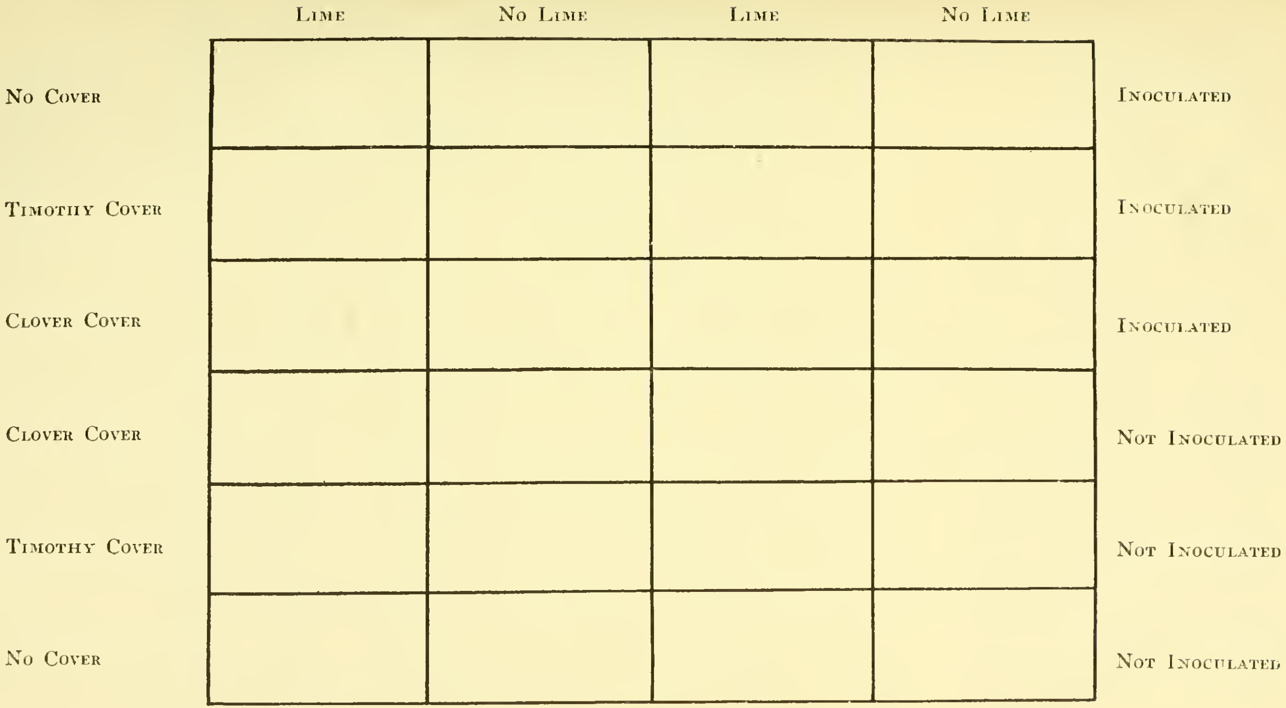
[5] Since the clover winter-killed every year, its effect if any must be attributed to the very small growth between sowing and freezing of the soil.

[6] These and subsequent determinations were made by F. W. Morse, Henri D. Haskins, and L. S. Walker, chemists on the staff of the Massachusetts Agricultural Experiment Station. The determinations were made on air dried soils by the Clark and Lubs colorimetric method. The water extract was made by adding 200 cc. of distilled water to 20 grams of air-dry soil in a flask and allowing it to stand about 1 hour with frequent shaking. The extract was then filtered by turning the soil mixture on a small filter in a large funnel. The first portions of the filtrate were returned to the soil flask until the extract was running clear. By this time, the paper was filled with soil, and the filtration was through soil supported by a small paper. By this means, any absorption by the paper was reduced to its lowest terms.



	LIME	NO LIME	LIME	NO LIME	
NO COVER					INOCULATED
TIMOTHY COVER					INOCULATED
CLOVER COVER					INOCULATED
CLOVER COVER					NOT INOCULATED
TIMOTHY COVER					NOT INOCULATED
NO COVER					NOT INOCULATED

FIGURE 1. Diagram of Field Experiments Showing Inoculation, Cover Crop, and Lime Treatment of Plots.

May in 1922, 1923, and 1924, and in April, 1925.

During each growing season observations on growth were recorded. Immediately after the crop was harvested roots from each plot were examined for black root-rot.

No yield records were taken in 1921 because of the uneven stand, due principally to setting at different periods. When the crop of 1922 was harvested, 160 plants from the four center rows of each plot were weighed. These green weights are recorded in Table I. At the time of harvesting in 1923, 1924, and 1925, the tobacco from each entire plot, except for the borders, was hung, stripped, and cured separately. The weights of cured leaves are tabulated by plots in Table I, and the results summarized in Table II. Sorting records for the crop of 1925 were made, and the percentage for each grade and length of leaf in each plot is given in Table III.

The work and results of each of the last four years are presented separately before discussing conclusions from the whole experiment.

Season of 1922

Throughout the summer it was apparent that (1) the timothy strips were making a poorer growth than those which had no cover crop or had clover; (2) the limed plots were making a better growth than the corresponding unlimed plots both on the inoculated and uninoculated parts of the field; (3) the inoculated half was not making as much growth as the uninoculated. These field observations were all substantiated by the yield records as given in Table I and summarized in Table II. This shows that by liming there was a gain of 12 per cent both on inoculated and uninoculated plots; by the use of a timothy cover crop there was a loss of 13 per cent on the inoculated and 18 per cent on the uninoculated half; and finally that the inoculated half was 15 per cent lighter all through than the uninoculated half. After cutting the tobacco, some of the roots from each plot were dug and washed. Lesions were found on practically all of the roots from the inoculated plots, but were not much worse on the limed than on the unlimed plots. They were located especially on the large roots at the bottom of the stalk where the roots had to grow through the handful of infested earth that was deposited at planting time. A few lesions were found on the roots from the uninoculated half.

In 1922 the use of lime was associated with an increase in the yield of tobacco, and was not associated with any great increase in the amount of root-rot.

This year there was a decided loss in weight of tobacco following the timothy cover crop. The percentage of loss from timothy was not as heavy on the inoculated half as on the uninoculated half.

Inoculated plots uniformly yielded a lighter crop than uninoculated, although examination of the roots did not indicate very severe infection. Most of the injury was in the region where the handful of infested soil was in contact with the roots and not general over the whole root system.

Season of 1923

About the middle of the summer it became apparent that in the infected half of the field the tobacco on the limed strips was lagging behind the unlimed strips in growth. This difference increased throughout the summer. The fact that a similar difference was not apparent on the uninoculated half indicated that the dwarfing effect was due to the influence of lime on the root-rot. When the roots were examined it was found that (1) the disease was very bad on all the inoculated limed plots, (2) the lesions were fairly prevalent on the roots of the unlimed inoculated plots (but much less so than on the limed plots), (3) there were frequent lesions on the uninoculated limed plots, and (4) only rarely could a lesion be found on the uninoculated, unlimed plots.

The results noted in 1923 may be summarized as follows: In the inoculated half of the field, the yield on limed plots was 16 per cent less than the yield on unlimed plots. In the uninoculated half of the field, the yield on limed plots was still 7 per cent more than the yield on unlimed plots, but this was a drop of 12 per cent from the previous year. On the inoculated half of the field even the unlimed plots suffered some loss from black root-rot, the yield being about 8 per cent less than on unlimed plots in the uninoculated part of the field.

In 1923 there was a small loss from the use of timothy, and, as in the preceding year, this loss was less on the inoculated than on the uninoculated plots.

Season of 1924

It became apparent early in the season that the limed plots were making a much poorer growth than the corresponding unlimed ones. This was particularly striking on the inoculated half, but it was also quite apparent from the poor growth that there were many places in the uninoculated half where root-rot was doing serious danage. It was plainly evident that root-rot was no longer confined to the inoculated end of the lime strips but that it was now present even to the extreme opposite end. A second very apparent fact was that there were some very good plots of tobacco (unlimed) in the inoculated part of the field, showing that the effect of very thorough inoculation was not lasting when the soil condition was not right. These observations during the growing season were substantiated by examination of the roots after the crop was harvested. It was then found that, irrespective of inoculation, the number of lesions was very small on all plots which had not been limed. On the limed strips, lesions were particularly numerous on the roots from the inoculated plots; but many of the roots from the other end were in just as serious condition, while others were relatively free. This indicated that on the uninoculated limed plots, the infestation was still uneven. Nevertheless it seemed to be spreading rapidly in these. The cured weights per acre as given in Tables I and II showed a loss from liming of 17 per cent on the inoculated plots and 12 per cent on the uninoculated plots.

In 1924, the fourth year of the experiment, the loss from black root-rot on limed plots was more severe than in the previous years, although no lime was applied this year.

In the unlimed plots, the amount of root-rot was small, whether or not the plots were inoculated. The yield on the inoculated plots was only 4 per cent less than on the corresponding uninoculated plots.

For the third successive year a reduction in yield was associated with the use of the timothy cover crop.

Season of 1925

The effect of lime on black root-rot and yield and the effect of timothy cover crop on yield were never more conspicuous than in 1925, although no cover crops had been planted and no lime applied since 1923.

Throughout the season growth was much superior in unlimed plots to growth in limed plots. It was apparent that on plots which had had a cover crop of timothy in previous years the tobacco was making a better growth than on plots which had never had a cover crop of timothy. In other words, the depressing effect of timothy which had been observed in previous years was not in evidence after this cover crop was omitted for one year. There was no visible difference in growth between the inoculated and uninoculated halves of the field. It was evident that, regardless of inoculation, black root-rot was causing loss in all limed plots.

When the roots from all plots were examined at harvest time, an average of 98 per cent of the plants in all limed plots was found to be severely infected with black root-rot. In unlimed plots an average of only 14 per cent of the plants showed symptoms of this disease, and infection on them was slight. The previous cover crop was found not to affect the amount or severity of black root-rot. Infection, as revealed by the examination of the roots, was the same on the inoculated and uninoculated parts of the field. Brown root-rot was slightly more pronounced on limed than on unlimed plots, but the difference was small.

The soil in limed plots had, in April 1925, pH values from 6.4 to 7.0. In all these, plants were severely infected and there were no visible differences between them as regards infection. The soil in unlimed plots ranged in pH values from 4.5 to 5.0. Infection in these plots was absent or slight, and there were no appreciable differences between them.

In 1925 the yield on inoculated plots was no less than the yield on plots not inoculated. The black root-rot fungus was evidently present in all plots, but had not become established in unlimed plots because of unfavorable soil conditions. It had, however, become established in limed but uninoculated plots. The black root-rot fungus is probably present in all tobacco soils, but it is evident that it causes no loss in soils having a reaction unfavorable to the fungus.

The average reduction in yield due to liming (35 per cent) was greater in 1925 than in any previous year of the experiment, although no lime was applied in either 1924 or 1925. During this two-year period without more lime added, the soil in the limed strips had, however, become slightly less acid. The omission of lime for two years on land on which tobacco was grown continuously did not result in any immediate relief from black root-rot. The greater loss in 1925 was probably not directly due to any change in the soil reaction, but to the fact that the soil is becoming more completely infested with the fungus.

The injurious action of lime as expressed in black root-rot was not more pronounced in its effect on yield than on quality and value. This is recorded in Table III under per cent darks, seconds, mediums, fillers, and brokes. The average per cent mediums and seconds on limed plots was 6, and on unlimed plots 22. The average per cent fillers on limed plots was 39 and on unlimed plots 17.

In 1924, for the third consecutive year, the use of timothy cover crop was associated with a reduction in yield. No cover crop was sown in 1924. In

1925 the plots which had previously had a timothy cover crop yielded more than plots on which a cover crop had never been grown. The average increase of plots which had had timothy cover crop over plots which had had no cover crop was 17 per cent. The increase following timothy was greater on limed than on unlimed areas. An examination of roots showed that after the omission of timothy cover crop for one year there was no significant difference between the amount or severity of brown root-rot on plots with and without timothy cover crop. The depressing effect of timothy cover crop on tobacco seems to disappear if the cover crop is omitted for but a single year.

Discussion of the Five-Year Experiment as a Whole

Occurrence of Thielavia in Tobacco Soils and Rate of Infestation

This fungus probably occurs to a limited extent in all of our soils. It has been shown that it occurs on the roots of nearly a hundred other species of plants besides tobacco (6). Many of these are common cultivated and weed plants. Further investigation would undoubtedly show that there are many other hosts. But even though its host plants were not present—they do not seem to be necessary—it apparently lives indefinitely in the soil on dead organic matter. In the examination of tobacco roots from fields which appeared quite normal and healthy above ground there are usually found occasional lesions of black root-rot. The reason that most Connecticut Valley tobacco fields do not suffer severely from black root-rot is not the absence of the fungus, but the maintenance of a soil condition which is unfavorable for its rapid propagation. Soil reaction is probably the most influential factor. An extensive survey of Massachusetts tobacco soils has not been made, but those which have been tested have been fairly acid with a reaction ranging between pH 4.5 and 5.8 except where they have been limed within a few years. Within this range there seems to be very little spread and the degree of infestation is light. But when raised above this range by application of lime or other alkaline substances, conditions are made more favorable to growth of Thielavia and the soil becomes more heavily infested. Increase in degree of infestation however is a slower process than has been commonly supposed. Most investigators of the disease have assumed that when acidity was reduced the disease would immediately become serious. In our own experiments it was not until the second year after liming was started that a high infestation was secured. We have seen a number of cases where growers have applied lime or wood ashes and the effect the first year was an increase in the yield of tobacco. It was only in the second or third year after liming that the trouble became serious. Hutcheson and Berger (4:7) noticed in their experiments that the first effect of lime was beneficial but its ultimate effect was to reduce the yield. It has been the common experience of those who have tried to produce the disease by soil inoculation that their first attempts were unsatisfactory. Since infection of the roots is local, i.e., the fungus does not travel far from the point where it enters the root, the amount of damage is in direct proportion to the number of places at which the root has been infected by the fungus. The degree of soil infestation must therefore be high before the disease becomes serious.

Similarly it is probable that a return of infested soil to a more acid condition will not be immediately followed by a great reduction in the amount of black root-rot. The results in 1925 indicate that the omission of lime and the continuous culture of tobacco do not quickly result in the disappearance of black root-rot injury. Further field work on this point is in progress.

Effect of Lime on Yield of Tobacco in the Absence of Root-Rot

It has been previously mentioned (p. 121) that certain investigators have found that the yield of tobacco was increased by liming the soil, and one of the objects of the work at the Massachusetts Agricultural Experiment Station was to determine whether such was the case under our conditions and if so, to measure the extent of increase. This was also a necessary preliminary to drawing any conclusion as to the effect of liming on root-rot. No records of yields for the first year of the experiment (1921) were made. The records of the second year show an increase of 12 per cent on both the inoculated and uninoculated parts of the field. Theoretically, this should have been larger the first year, since root-rot must have taken a slight toll the second year. During the third year the loss from root-rot more than counterbalanced the gain from lime on the inoculated part, and there was a total loss of 16 per cent. Even on the uninoculated part, root-rot was beginning to reduce the gain which would otherwise have been anticipated from liming, but there was still a final gain of 7 per cent on this half. During the fourth year of the experiment, root-rot had increased to such an extent that it more than overcame the benefit of the lime on the uninoculated part, and we had a final loss even on that side of 12 per cent as opposed to a 17 per cent loss on the inoculated part. In 1925 root-rot had increased so much that the benefit of lime was overcome even more and the loss was about 35 per cent on both the inoculated and uninoculated areas. This is a much greater loss than could have been predicted, since at the previous rate of progress the loss would have been about 17 per cent.

In answer to the first question which was proposed as the object of this experiment we may state that the immediate effect of lime in this soil was to increase the yield. In this case it was 12 per cent the second year. Undoubtedly, the degree of increase from liming depends on the reaction of the soil before application is made. On a soil less acid than this, one would hardly expect the same degree of increase.

How Acid Should the Soil Be?

It has again been demonstrated that the ultimate effect of heavy applications of lime is to increase root-rot and thus reduce yield. The facts that (1) neutral calcium salts such as land plaster do not produce this effect and (2) other alkaline substances such as carbonate of potash do produce it, show that the influencing factor is not the calcium but the alkaline character of the lime. The less acid or neutral soil thus produced does not render the tobacco plant more susceptible to attack but it favors the growth of the fungus and results in a larger number of lesions on the root system. Although there are probably no tobacco soils free from Thielavia, it is apparent that many of them, by virtue of their acid reaction, are so nearly free that their infestation is negligible; while others, by virtue of their less acid reaction, are so heavily infested as to render profitable tobacco growing impossible. The all important question now is: Just where is the dividing line between safety and certain loss? Just what degree of acidity must a soil possess in order to be safe from root-rot?

The data on the soil and crop of 1924 are valuable in determining the location of the dividing line, because at that time the soil must have more nearly reached an equilibrium after the treatment of the three preceding years, and because this equilibrium was not disturbed by artificial inoculation or application of lime in 1924. Correlating for that year the root inspection records, the yield and sorting records and the soil reaction records, we find that root-rot was not serious on any of the twelve plots which had an average reaction of slightly over 5; but that it caused serious damage on all the inoculated and most of the uninoculated plots with an average of 5.9. By using individual plot records it may be confined more closely. Especially instructive is the record of plot 13 which kept a reaction of 5.5-5.6 throughout the three years and which was inoculated as thoroughly as any other plot in the field for three years; but on the 4th year only an occasional lesion on the roots could be found and it was the best plot in the field. Similarly, an inspection of the individual limed plots indicates pretty severe loss at 5.8.

In 1925, soil reactions were determined in April and in October. The pH values were found to have changed considerably during the growth of the tobacco in 1925. This was especially conspicuous in the limed plots, in which the soil became more acid, probably because of the removal of some of the lime by the crop. The pH values determined in April are indicative of the environment in which the crop grew. The reaction of plots without lime was between pH 4.5 and 5.0, and in these plots black root-rot caused no apparent loss. Limed plots had pH values between 6.4 and 6.9, and in all of them black root-rot caused serious damage. There were this year no plots having pH values between 5.0 and 6.4, and so the critical point cannot be located any more closely than has been done above on the basis of the results in 1924.

Experiments in pots in the greenhouse, which are to be described in a later paper, have led us to the conclusion that loss from black root-rot occurs whenever the pH value of the soil is 5.9 or higher, and that loss from black root-rot does not occur at pH 5.6 or below, except in exceptionally cold soils.

We may *therefore conclude that the critical point is somewhere between 5.6 and 5.9.* It is apparent however that there cannot be in reality a critical *point* but rather a critical *region*, below which damage from root-rot may be expected to be little if any, and above which root-rot is almost certain to cause trouble. There are at least three reasons why this region cannot be defined more accurately than the limits given above:

1. The transition from a soil reaction unfavorable for growth of Thielavia to a reaction which favors is a matter of degree—not of plus and minus.

2. During a very warm summer the critical region would probably be higher since a higher soil temperature reduces the effect of root-rot, as has been shown experimentally by Johnson and Hartman (7:60). A cold summer on the other hand would probably depress the critical region toward the acid range.

3. On compact, poorly drained soil black root-rot is commonly worse than in looser soil in the same field, due probably to the difference in the rate of leaching and to lower soil temperature. This also is in accord with the experimental results of Johnson and Hartman (7:80). It is not improbable that

on such a soil the location of the critical region would be lower. On the basis of the yields of the last three years it may be stated that, as the acidity of the soil becomes less above 5.9, the loss caused by black root-rot becomes greater. (The upper limit of alkalinity has not been determined.) Plots on the limed areas in this experiment may be placed in four groups on the basis of the pH values of their soils. These are correlated with average yields as follows:

pH 5.9 to 6.1 — yield 1233 pounds
" 6.1 " 6.2 — " 1183 "
" 6.2 " 6.3 — " 1120 "
" 6.3 " 6.4 — " 1039 "

We have, then, quantitative evidence of the increasing injury from black root-rot which results when by the addition of the lime the soil is made less and less acid to a point beyond pH 5.9.

How Much Lime May Be Used with Safety?

If the soil has reached such a point, and if it is seriously infested with the black root-rot fungus, what then may be done? If no further lime is applied and if tobacco is continuously grown on such soil, the loss of lime by leaching and by removal in the plant will gradually result in a more acid condition. Of course the loss from black root-rot may be so great as to make tobacco growing on such land unprofitable. Continuous tobacco, no further liming, and the use of acid fertilizers, such as sulfate of ammonia and sulfate of potash, are all the remedial measures to be suggested at this time. A quicker method of increasing soil acidity is desirable, and this matter is now under investigation.

The Effect of Timothy

Since timothy is extensively used and widely recommended as a cover crop for tobacco soils, it was assumed at the outset that it was known to increase the yield of tobacco by virtue of the organic matter which was added to the soil or the plant food which was saved from leaching through its use. It was included in the present experiment to see whether it influenced the damage from black root-rot and as a check against the clover cover crop which was supposed to increase root-rot because it is a host plant of Thielavia. At the end of the first season, therefore, it was a surprise to find that both the inoculated and uninoculated timothy plots showed a reduction in yield—13 per cent and 18 per cent on the inoculated and uninoculated plots respectively. It could not have been a result of the timothy depleting the soil water because 1922 was an extremely wet year. Losses from the use of timothy both on the inoculated and uninoculated plots, but in a smaller degree, were also recorded in 1923 and 1924. Certain plots at times showed small increases over adjacent plots without cover, but considering the experiment as a whole, the conclusion is inescapable that the effect of timothy has been to decrease both the yield and value of the tobacco. This is in agreement with data recently published by Jones (8) who reports an average decrease in yield of 13 per cent associated with the use of the timothy cover crop. The percentages of loss during two of the years were not so high on the inoculated as on the uninoculated plots, but the reverse was true the third year. Certainly there was not, on the whole, sufficient evidence from either the yield data or the examination of the roots to prove that timothy had any influence on the prevalence or severity of black root-rot.

In 1925, after one year's omission of cover crops, the plots which had had timothy cover crops yielded 17 per cent more than the plots which had never had cover crop. It would appear from this that the depressing effect of timothy cover crop quickly disappears and is replaced by a beneficial effect when the cover crop is not sown for one year. This increase following timothy after an interval of one year was greater on limed than on unlimed plots. In this connection it is interesting to consider the previous depressing effect of timothy on limed versus unlimed plots. For the three years previous to 1925, the average reduction in yield associated with the use of timothy cover crop was 5 per cent on limed plots and 10 per cent on unlimed plots.

When the roots of the plants on the timothy plots were compared with those on the adjacent plots without cover in years previous to 1925, it was found that many of the laterals—especially the lower ones—were brown and dead. The symptoms were quite typical of the disease which is now commonly called brown root-rot. The disease was not entirely lacking in any of the plots but was certainly more pronounced on the timothy plots. On the timothy plots which had been limed, black root-rot was also present, and it was not always possible to separate the influence of the two; but on the unlimed plots the brown root-rot was unmistakable. Brown root-rot, then, is apparently one of the causes of depressed yields on the timothy plots. It is known that timothy in rotation encourages this disease, and it is not surprising that we should now find the same effect from timothy used as a cover crop. This, however, is not a satisfying explanation, because we do not yet know what brown root-rot is. Whether or not it is caused by soil organisms or by toxins or malnutrition has never been determined. We are not even sure that all the tobacco-sick soil troubles which we include under the title of brown root-rot are the same. The only characters they have in common are the presence of some dead brown roots and consequent reduced growth.

Pure Culture Experiments on the Relation of H-ion Concentration to Growth of Thielavia

From the preceding, it is apparent that the adverse effect of lime on tobacco is due to the favorable influence of an alkaline reaction on the growth of Thielavia. In order to see whether this conclusion is supported by growth of the fungus in pure culture, synthetic culture media (Czapek's) were prepared and adjusted to the following reactions: 1.5, 2.0, 3.05, 3.45, 3.8, 3.9, 4.25, 4.55, 5.35, 6.05, 6.2, 7.2, 7.9, 8.55, 8.9, 9.6, 9.9, 11.05, 12.1, and 12.9. The reactions were determined both colorimetrically and electrometrically. Three series of cultures were made, one in tubes and the others in Petri dishes. Records of measurements and notes on growth were made at intervals of 3 or 4 days. Briefly summarized, the results were: On all cultures between 6.05 and 12.9 the growth consisted of a dense black mat of mycelium on the surface and dark hyphae under the agar. Both chlamydospores and conidia were produced in great abundance. Within this range no difference in character or quantity of growth could be observed. Apparently the reaction was optimum throughout this entire range. But below this it was otherwise. At 5.35 the rapidity of growth began to decrease. Below 5.35, all growth on the surface ceased and even under the surface it was progressively more scanty down to 3.05. Below this, growth ceased altogether. The production of chlamydospores also decreased progressively with the scantiness of growth until there were none at all at 3.05. A few conidia were produced even to the most acid point where mycelium grew.

Since in pure culture the fungus will grow even at reactions which are more acid than any tobacco soils, it is pertinent to ask why we do not have loss from root-rot below 5.5. The answer is probably to be found in the difference between conditions which the fungus encounters in a sterile artificial medium and what it encounters in its natural medium, the soil. In the latter case it meets keen competition from other soil organisms and it is only the strong vigorous growers that get the available food and thrive. But, as was noted above, Thielavia at 5.35 is beginning to lose its vigor and at more acid ranges it dwindles to nothing. When in its weakened condition due to unfavorable reaction it is being crowded out by other organisms better adapted to acid conditions, it is not strange that Thielavia should be able to make but little headway at 5.35 or lower. Incidentally it should be kept in mind that Thielavia does occur sparingly on roots in more acid soils, and the lesions are just as pronounced but are not numerous enough to cause much loss. The critical point at which vigor of growth begins to diminish is thus lower than 6.05 and higher than 5.35. Thus it must fall somewhere in the region which we have called the critical region, and the results from the pure culture tests support those of the field tests.

SUMMARY

1. The immediate effect of liming an acid soil was to increase the yield of tobacco.

2. If sufficient lime is added, black root-rot is ultimately promoted, and there is consequently a reduction in yield.

3. Black root-rot is present in most soils but is more injurious in nearly neutral soils because the causal fungus, *Thielavia basicola*, grows more rapidly and vigorously in a nearly neutral medium.

4. In the field under experimentation, black root-rot caused little or no loss in soils more acid than pH 5.6. It caused severe loss on all soils less acid than pH 5.9. It should be understood that this critical region between pH 5.6 and 5.9 is an intermediate zone which may be shifted to a somewhat higher or lower position by variations in temperature and compactness of soil, and by differences in the degree of infestation of the fungus in the soil. Growth of the fungus in pure culture on media confirmed the results in the field.

5. As the soil becomes less acid above pH 5.9, the loss from black root-rot increases. The upper limit of alkalinity has not been determined.

6. After repeated applications of lime brought the soil reaction to a point favorable to the fungus, the omission of lime for two years, with tobacco grown continuously meanwhile, did not result in any immediate reduction in the severity of black root-rot.

7. If, because of extreme acidity, lime is considered necessary, it should be applied with great caution and in small applications, always preceded by determinations of soil reaction in order to avoid approaching too closely the danger point of pH 5.9.

8. The use of timothy cover-crop was found to have no significant effect on the prevalence of black root-rot.

9. The use of timothy cover-crop reduced the yield of tobacco for three consecutive years. This effect was associated with brown root-rot.

10. When timothy cover crop was omitted for one year, the depressing effect of timothy quickly disappeared and was replaced by a beneficial effect. In these experiments the yield on plots so treated exceeded by 17 per cent those without cover crop.

LITERATURE CITED

1. Briggs, L. J. The field treatment of tobacco root-rot. U. S. Dept. Agr. Bur. Plant Indus. Circ. 7: 5-8. 1908.
2. Chapman, G. H. Tobacco investigations, progress report. Mass. Agr. Expt. Sta. Bul. 195: 1-38. 1920.
3. Hartwell, B. L. and S. C. Damon. The comparative effect on different kinds of plants of liming an acid soil. R. I. Agr. Expt. Sta. Bul. 160: 407-446. 1914.
4. Hutcheson, T. B. and D. J. Berger. Experiments with bright tobacco and other crops grown on bright tobacco farms. Va. Agr. Expt. Sta. Bul. 233: 3-19. 1923.
5. Jenkins, E. H. and G. P. Clinton. Root-rot of tobacco. Conn. Agr. Expt. Sta. Bul. of Immediate Information 4: 1-11. 1906.
6. Johnson, James. Host plants of Thielavia basicola. Jour. Agr. Res. 7: 289-300. 1916.
7. Johnson, James and R. E. Hartman. Influence of soil environment on the root-rot of tobacco. Jour. Agr. Res. **17**: 41-86. 1919.
8. Jones, J. P. Havana seed tobacco as influenced by timothy cover crop. Mass. Agr. Expt. Sta. Circ. 73: 1-3. 1925.
9. McCall, A. G. Fertilizers for Maryland soils. Md. Agr. Expt. Sta. Bul. 247: 117-151. 1922.

TABLE I. Treatment, Yields, and Reaction Analyses by Plots throughout the Five Years of the Root-Rot Experiment

Plot	Inoculation	Cover Crop 1921–24	Lime in May 1921	pH May 1922		Lime in May 1922	Green Weight 160 Plants Sept. 1922 Lbs.	pH May 1923		Lime in May 1923	Cured Leaves Lbs. per Acre 1923	pH May 1924		Cured Leaves Lbs per Acre 1924	pH April 1925		Cured Leaves Lbs. per Acre 1925
1	+	None	None	5.0	Average 5.11	None	396	5.2	Average 5.56	None	1231	4.9	Average 5.01	1453	4.6	Average 4.76	1131
2		Timothy		5.2			201	6.0			1372	5.2		1320	4.6		1362
3		Clover		5.1			345	5.2			1358	4.9		1449	5.0		1339
4	—	Clover		5.1			349	5.5			1590	4.8		1468	5.0		1184
5		Timothy		5.2			348	5.7			1457	5.0		1528	4.8		1237
6		None		5.0			387	5.8			1670	5.3		1608	4.6		1187
7	+	None	Ground Limestone 2 tons per acre	5.4	Average 5.73	Precipitated Lime 1 ton per acre	323	6.2	Average 6.06	Agricultural Lime 2 tons per acre	976	6.0	Average 5.9	1150	6.9	Average 6.7	696
8		Timothy		6.2			353	6.3			891	5.8		1315	6.7		1050
9		Clover		6.2			349	6.2			1216	6.0		1182	7.0		748
10	—	Clover		5.6			388	5.7			1599	6.0		1324	6.4		766
11		Timothy		5.5			374	6.2			1373	5.7		1500	6.5		1005
12		None		5.4			477	5.8			1500	5.8		1354	6.7		632
13	+	None	None	5.6	Average 5.70	None	378	5.5	Average 5.68	None	1472	5.5	Average 5.03	1621	4.7	Average 4.72	1492
14		Timothy		5.8			348	5.6			1245	5.0		1354	4.8		1344
15		Clover		5.7			301	5.6			1486	4.9		1566	4.8		1196
16	—	Clover		5.8			430	5.6			1641	5.0		1563	4.7		1303
17		Timothy		5.7			356	6.3			1269	5.2		1522	4.8		1433
18		None		5.4			441	5.5			1231	4.6		1488	4.5		1273
19	+	None	Ground Limestone 2 tons per acre	5.3	Average 5.77	Precipitated Lime 1 ton per acre	393	6.1	Average 6.05	Agricultural Lime 2 tons per acre	1132	5.8	Average 5.9	1278	6.5	Average 6.65	820
20		Timothy		6.0			391	6.0			1245	6.6		1117	6.7		888
21		Clover		6.5			394	6.2			1415	5.8		1257	6.7		796
22	—	Clover		5.5			471	6.0			1886	5.8		1313	6.4		732
23		Timothy		6.0			388	6.0			1316	5.8		1207	6.9		994
24		None		5.3			486	6.0			1401	5.6		1437	6.7		714

TABLE II. Summary of Yields for 1922, 1923, 1924, and 1925

Pounds per Acre

Treatments	1922 Green	1923 Cured	1924 Cured	1925 Cured
Average of all limed plots:				
Inoculated . . .	7340	1146	1217	868
Not inoculated . . .	8620	1579	1356	807
Average of all unlimed plots:				
Inoculated . . .	6560	1361	1461	1319
Not inoculated . . .	7700	1476	1535	1269
Average of timothy cover plots:				
Inoculated	6460	1193	1277	1161*
Not inoculated	7320	1354	1439	1167*
Average of plots without cover crop:				
Inoculated	7450	1203	1375	1034
Not inoculated	8960	1450	1472	951
Average of all plots:				
Inoculated	6960	1253	1338	1076
Not inoculated	8160	1494	1443	1038

Percentage Gain (+) or Loss (—)

Treatments	1922 Green	1923 Cured	1924 Cured	1925 Cured
From liming:				
Inoculated	+12	—16	—17	—34
Not inoculated	+12	+ 7	—12	—36
From timothy cover:				
Inoculated	—13	— 1	— 7	+12*
Not inoculated	—18	— 7	— 2	+23*
From inoculation:				
Limed	—15	—27	—10	+ 8
Unlimed	—15	— 8	— 5	+ 4

*Timothy not sown in 1924, no cover crop plowed under in 1925.

Table III. Sorting Record of Crop of 1925

Plot	Treatment	pH*	Yields per Acre Lbs.	Darks		Seconds		Mediums		Fillers	Brokes
				Per cent	Length Inches	Per cent	Length Inches	Per cent	Length Inches	Per cent	Per cent
	No Lime:										
1	No cover crop	4.6	1131	50.9	15–25	24.9	15–25	0.6	Not sized	15.8	7.8
2	Timothy	4.6	1362	56.0	15–25	18.7	15–23	None		16.0	9.3
3	Clover	5.0	1389	49.3	15–27	22.9	15–23	None		21.5	6.3
4	Clover	5.0	1184	53.6	15–25	17.9	15–23	0.9	21–23	20.4	7.0
5	Timothy	4.8	1237	51.6	15–25	21.7	15–23	2.5	21–25	17.8	6.4
6	No cover crop	4.6	1187	51.2	15–27	21.1	15–25	2.8	21–25	17.8	7.1
	Lime:										
7	No cover crop	6.9	696	59.8	15–21	0.5	15	None		39.7	None
8	Timothy	6.7	1050	44.4	15–21	27.9	15–21	None		27.0	0.7
9	Clover	7.0	748	46.5	15–21	3.0	15.19	None		48.6	1.9
10	Clover	6.4	766	54.9	15–21	1.9	15–19	None		43.2	None
11	Timothy	6.5	1005	65.6	15–23	5.3	15–19	None		27.5	1.6
12	No cover crop	6.7	632	41.7	15–23	1.5	15–19	None		56.1	0.7
	No Lime:										
13	No cover crop	4.7	1492	56.8	15–27	23.5	15–25	0.6	Not sized	13.6	5.5
14	Timothy	4.8	1344	55.6	15–27	16.6	15–23	None		17.2	10.6
15	Clover	4.8	1196	50.8	15–27	22.3	15–23	0.6	Not sized	16.4	9.9
16**	Clover	4.7	1303	54.9	15–27	14.7	15–25	2.2	21–25	15.4	12.5
17	Timothy	4.8	1433	51.5	15–27	21.5	15–23	1.6	21–25	17.5	7.9
18	No cover crop	4.5	1273	51.2	15–27	19.2	15–25	2.6	21–25	17.5	9.5
	Lime:										
19	No cover crop	6.5	820	51.9	15–21	5.6	15–19	None		41.6	0.8
20	Timothy	6.7	888	63.1	15–21	9.3	15–19	None		27.1	0.5
21	Clover	6.7	796	46.5	15–21	6.0	15–19	None		45.0	2.5
22	Clover	6.4	732	44.6	15–23	3.9	15–19	None		50.5	0.9
23	Timothy	6.9	994	52.9	15–23	13.7	15–21	None		26.6	6.6
24	No cover crop	6.7	714	38.7	15–23	2.9	15–19	None		56.6	1.5

*April, 1925. **0.3 per cent (3.9 lbs.) overdamp.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 230 APRIL, 1926

RESEARCH SERVICE TO MASSACHUSETTS ANIMAL INDUSTRY

PROGRESS REPORTS

This bulletin contains five papers summarizing the experimental work of the Station which has to do with the feeding of farm animals. More complete reports of some of this work have been published in scientific journals. The subjects reported upon are as follows:

Mineral Matter for Dairy Cows	J. B. Lindsey and J. G. Archibald
Skim Milk Powders in the Rearing of Young Calves	J. B. Lindsey and J. G. Archibald
Better Feed from Permanent Pastures	Sidney B. Haskell
The Utilization of Feeds by Horses	J. B. Lindsey and J. G. Archibald
Improving the Feeding Value of Grain Hulls and Sawdust	J. G. Archibald

Requests for bulletins should be addressed to the
Agricultural Experiment Station
Amherst, Mass.

MINERAL MATTER FOR DAIRY COWS

By J. B. LINDSEY and J. G. ARCHIBALD

INTRODUCTION

It is a well-known fact that all animals require a certain amount of mineral matter in their diet. The fondness of all classes of stock for common salt is so well known that mention of it seems almost superfluous. The sight of a cow chewing a bone or an old shoe, licking the earth, or gnawing at a fence rail is familiar to anyone who has ever lived on a farm.

Until recent years, however, comparatively little attention has been paid to these outward evidences of mineral hunger, because of the belief that the feeds commonly fed to cows contained sufficient mineral matter (common salt excepted) for their needs. Gradually it has come to be realized that such is not always the case and that shortage of available mineral matter, under certain circumstances, may be a limiting factor in growth and production. The situation has been well summed up by the late Professor Armsby, who said: "Most feeding stuffs, and particularly the mixed rations of farm animals, contain what appear at first sight to be much larger amounts of ash ingredients than the body requires . . . . . This is doubtless true of animals living in a state of nature, but it is a questionable assumption under the artificial conditions to which many farm animals are subjected."

This point of view has become prevalent only within the past decade. Its establishment on a firm basis of fact has been due, in large measure, to the work done in recent years at certain of the experiment stations in this country. For example, it has been shown that in spite of liberal feeding, heavy milking cows excrete daily more mineral matter, particularly calcium and phosphorus, than they consume, or are in what is termed negative mineral balance, and it is only when they reach the advanced stages of lactation (10 pounds of milk daily) that the reverse is true; that is, that they consume more minerals than they give out. There is, however, no record of prolonged experiments on the effect of feeding mineral supplements to milking cows to help out a mineral deficiency. Realizing the dearth of such information and its importance, this department instituted such an experiment in the autumn of 1921, which, modified from time to time to meet changing conditions in the station herd, is still in progress. This paper is a brief report of the work up to October 1, 1925.

PLAN OF THE EXPERIMENT

The main features of the experiment have been:

1. Feeding the whole herd a ration deficient according to prevailing standards in calcium and phosphorus but adequate in all other respects.
2. Division of the herd into halves as nearly alike as possible, and the addition to the grain ration of one group, of supplemental calcium and phosphorus in the form of special steamed bone meal containing but little animal matter.

3. Including in the experiment the heifer calves from the cows in the two groups and keeping them as far as possible on the same diet as their dams, in order to see if any effects of the treatment are more marked in the second or even in the third generation than in the original animals used.
4. Observation of the effects of the feeding upon:
   - (a) the general condition and weight of the animals,
   - (b) growth of heifers,
   - (c) milk production,
   - (d) composition of the milk, especially its content of calcium and phosphorus,
   - (e) reproduction, under which general heading have been observed:
     - (1) recurrence of heat,
     - (2) difficulties in getting cows bred,
     - (3) number of abortions and retained afterbirths,
     - (4) condition of the calves at birth and subsequently.

THE HERD

The station herd is made up of high-grade Holsteins with a few Jerseys, and usually numbers, including young stock, eighteen to twenty head. At present there are nineteen animals included in the experiment,—fourteen milch cows, one two-year-old heifer, and three eight-months-old heifers.[1] There have of necessity been some changes in the herd since the experiment was started, but of the nineteen individuals originally included, ten are still in the herd. Since the commencement of the experiment in December, 1921, the milking herd has had an average annual production per cow of 8000 pounds of milk, testing 4.21 per cent of fat.

All cows are given a two months dry period during which time they are liberally fed, but they are not sent to pasture. They are maintained on dry feed the year around, except for a period commencing about June 25 and ending about October 10, during which time each cow is fed about 25 pounds daily of such green soiling crops as oats, millet, sorghum and fodder corn, as a substitute for a portion of their hay. Ensilage, roots or legume hay have not been fed during the experiment.

RATIONS FED

The rations have purposely been made as poor in mineral matter as a wise choice of feeds, other factors being considered, would permit. The hay has consisted principally of timothy, with some red top, blue grass and orchard grass.

The grain ration has consisted of the following mixture:

	Per cent
Ground oats	39¼
Gluten meal	20
Red dog flour	20
Wheat bran	20
Salt	¾
	100

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[1] All heifer calves are included in the experiment as soon as old enough to subsist on hay and dry grain. The age varies with the calf from five to seven months.

The mineral content of the entire ration was still further lessened by substituting for a portion of the hay, during certain periods of the experiment, such mineral-poor materials as chopped oat straw, starch, or apple pomace.

The whole herd has been fed as described above for four years, and in addition, one-half of the herd, known as the "bone meal" group, has received supplemental calcium and phosphorus in the form of steamed bone meal specially prepared for animal feeding. The bone meal was thoroughly mixed with the grain before feeding and the amount for each cow has varied with her weight and the amount of milk she gives, from three to eight ounces daily, the aim being to supply approximately a 60 per cent excess over the theoretical requirements of each cow. This excess is provided as a safeguard; for, although little is known about how completely mineral matter in the form of ground bone is utilized by the dairy cow, it is safe to assume that it is only partially digested and made available.

Results of the Experiment

General Condition and Weight of the Cows.

The condition of the animals has been carefully noted by means of observations made and recorded from month to month. At no time has it been possible to note any marked difference in the mature cows. Irrespective of the group in which they belong they have maintained themselves well. This has been especially true of the Holstein cows.

Among the young cows and heifers the effects of the low mineral ration have been much more apparent. Several of them are considerably undersized for their age, and present a general unthrifty appearance. Recently some of them have had very poor appetites, refusing at times both hay and grain. The young Jerseys seem to have been particularly susceptible, and while some of the Holsteins have also been affected they have stood up under the low mineral feeding better than the Jerseys. As with the aged cows the effects noted have been irrespective of whether they received bone meal or not, although recently there has been some evidence to favor the bone meal.

All of the cows that were mature at the commencement of the experiment have maintained their weights well, there being no significant variation from year to year in either group.

Growth of Heifers

Study of the growth records of the young stock in comparison with those of their dams shows that of twelve individuals, six are as large as their dams were at the same age and six are smaller than the dams were. These two groups are composed according to breed as follows:

Large as dam	*Smaller than dam*
Holstein—4	Holstein—3
Jersey—2	Jersey—3

According to grouping in the experiment they are divided thus:

Large as dam	*Smaller than dam*
Bone meal—3 (2H & 1J)	Bone meal—3 (1H & 2J)
No bone meal—3 (2H & 1J)	No bone meal—3 (2H & 1J)

So far, then, as growth records go the evidence is about evenly divided, there being nothing in favor of the bone meal.

Milk production

The milk yield has remained at a fairly constant average level all through the experiment. The average daily yield per cow from year to year is given below, *commencing two years before the experiment was started.*

Year	Average daily yield of milk per cow, lbs.
1920	21.87
1921	21.65
1922	22.67
1923	21.56
1924	21.06
1925	22.30

The above record is for the whole herd. Dividing the herd into the two groups, those that received bone meal and those that did not, we find the following records:

Year	Average daily yield of milk per cow, lbs.	
	"Bone Meal" Group	"No Bone Meal" Group
1922	22.20	23.13
1923	19.85	23.00
1924	21.36	20.76
1925	20.65	23.94

On this basis it would seem that the cows not receiving bone meal were the better producers. When we subjected our data to careful analysis, studying the records of the individual cows from year to year, and took into account the influence of breed, age, and length of lactation on the milk yield of the two groups, it was found that the evidence is not so favorable to the "no bone meal" group. In fact, it favors slightly the "bone meal" group of cows.

Composition of the Milk

The milk from each cow in the herd is sampled for five consecutive days each month. Total solids and fat have been determined in the composite samples each month during the course of the experiment. In addition the total ash, and calcium and phosphorus content of the milk have been determined from time to time,—on an average, about four times a year.

Average Composition of the Milk
since Commencement of the Mineral Experiment.*

(Expressed as percentages of the liquid milk)

	Whole Herd, (Dec. 1921-Oct. 1925)	"Bone Meal" Group.	"No Bone Meal" Group.
Total solids	12.74	12.83	12.67
Fat	4.21	4.27	4.16
Solids not fat	8.53	8.56	8.51
Total ash	0.724	0.722	0.725
Calcium (Ca)	0.117	0.118	0.117
Phosphorus (P)	0.096	0.093	0.098

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* These figures have been corrected for differences in the relative number of Holsteins and Jerseys in each group, otherwise the much richer Jersey milk might give the figures a wrong significance. In the case of total ash, calcium and phosphorus, they have also been corrected for any influence that difference in stage of lactation of the cows in the two groups might have. It is well known that as a cow advances in lactation her milk becomes richer. This correction has not been necessary for the total solids and fat, as they have been determined regularly every month for all cows.

Effect on Reproduction

Recurrence of Heat.

Regarding regularity, the records show the following:

Regularity	Whole Herd	"Bone Meal" Group.	"No Bone Meal" Group
Good	15	7	8
Fair	4	3	1
Poor	0	0	0

The average length of time after calving before the first heat has been:

"Bone Meal" group,	37 days
"No Bone Meal" group,	39 days

The condensed data show that both groups were quite similar in their behavior in these respects. In fairness, however, it must be stated that as the experiment has progressed, the cows that received the bone meal have tended to come in heat sooner after calving, while the reverse has been true of those that did not receive bone meal.

Difficulties in Getting Cows Bred.

Considerable trouble has been experienced in getting the cows with calf, some of them needing the attention of a veterinarian, and having to be served four or five times before they would hold. Up until the past year or so the trouble became somewhat more prevalent as the experiment progressed. Since then, for some unaccountable reason, the cows have improved considerably in this respect. The groups have been quite evenly divided with respect to it, as the accompanying figures show.

Average Number of Times Bred.

Year	"Bone Meal" Group.	"No Bone Meal" Group.
1922	1.60	1.67
1923	2.25	2.67
1924	2.67	2.57
1925	1.60	1.50

Abortions and Retained Afterbirths.

There have been three cases of abortion and one premature birth in the herd since the commencement of the experiment. Two of the abortions were in the "bone meal" group, the other one and the premature birth were in the "no bone meal" group. Two of the abortions were caused by accidents and it is doubtful if the other two were due to the effect of the experiment. There have been six cases of retained afterbirth, of which four have been in the "no bone meal" group. This fact may be of some significance, or it may be mere chance.

Condition of the Calves at Birth and Subsequently.

All calves dropped during the course of the experiment have either been raised to maturity or kept a sufficiently long time to enable us to form an accurate opinion as to their constitutional vigor. The following table summarizes the records.

Condition of Calves.

Group and Year.	Vigorous.	Good.	Fair.	Delicate
Bone meal				
1922	1	1	...	1
1923	2	...	2	1
1924	1	2	2	...
1925 (to Oct. 1)	2	...	1	...
Total	**6**	**3**	**5**	**2**
No bone meal				
1922	1	1	2	2
1923	2	2	2	1
1924	2	1	1	2
1925 (to Oct. 1)	2	4	1	...
Total	**7**	**8**	**6**	**5**

The only result of any significance here is the somewhat higher number of delicate calves from the "no bone meal" cows. Proportionately the difference between the groups in this respect is not so great as a first glance at the figures seems to show, the ratio being roughly 3 to 2 instead of 5 to 2. Also the delicate calves have with one or two exceptions been from Jersey cows, so that it is probable that breed characteristics have had more influence than has the experimental treatment.

SUMMARY

The object of the work reported here has been to ascertain what benefit may be derived from adding steamed bone meal, with the animal matter largely extracted, as a source of lime and phosphorus to the ration of dairy cows.

The entire herd has been fed for four years on a ration low in mineral matter, particularly in lime. One-half of the herd has had the deficiency made good in theory by adding bone meal to the grain.

The results in brief are as follows:

1. The experiment has had no appreciable effect on the general condition of the cows that were mature when it commenced. This has been especially true of the Holstein cows. The low mineral rations have adversely affected some of the young cows, as evidenced by their unthrifty appearance and poor appetite. The young Jerseys show this more than do the young Holsteins, although there are exceptions in both breeds. For a long time there seemed to be no difference in general condition between the "bone meal" and the "no bone meal" group; but recently there has been some slight evidence to favor the bone meal.

2. The mature cows have not shown any significant changes in weight, but about half of the young cows are smaller than their dams were at the same age. In this respect the evidence is about evenly divided, not favoring either group.

3. Milk production has been maintained well all through the experiment. The evidence on this point favors slightly the "bone meal" cows.

4. The composition of the milk has not been significantly affected.

5. The reproductive function has been more seriously disturbed than any other, considerable difficulty being experienced in getting the cows with calf. The two groups have been quite similar in this respect.

6. Each group has produced about the same proportion of strong, healthy calves. The "no bone meal" group has had a somewhat higher proportion of delicate calves, but this may have been due in part to breed characteristics.

CONCLUSIONS AND RECOMMENDATIONS

Our work has led us to the conclusion that while dairy stock, especially growing heifers, must have an adequate supply of lime in their food in order to attain maximum development and productive capacity, the advantage to be gained from the practice of supplying lime in the form of steamed bone meal seemed to be very slight.

While we have still much to learn on the subject of mineral feeding of cows, the following recommendations are tentatively made:

1. Supply lime and other minerals in feeds that are naturally rich in ash, rather than by supplementing feeds low in ash with bone meal or other lime salts. All the leguminous hays are high in lime, in addition to their very desirable protein content. Alfalfa hay contains five times as much lime as does timothy hay. There is as much lime in a ton of red clover hay as in 100 pounds of ordinary bone meal, and it is in what is probably a more desirable form. It is in the choice of roughage that care must be used. The ordinary grains and concentrates are characterized by relatively low lime and

high phosphorus content, so that in so far as ash requirements are concerned it makes little difference what grain ration is fed.

2. All dairy cows should have a dry period of two months, during which time they should be liberally fed on a legume roughage, or on early cut hay containing clover, or on rowen, as well as on some grain to make up for the losses in mineral matter during the period of heavy milking. Good pasturage will also prove very satisfactory.

3. Growing heifers should receive special care with respect to the ash content of their rations. Here again some kind of properly cured legume or clover-mixed hay is the best safeguard.

4. Put the bone meal and other mineral substances on the land, rather than in the manger. Used in this way the yield and ash content of the crop are likely to be increased and thus indirectly the ash requirements of human beings and animals will be taken care of.

5. Common salt is the one exception to all the above statements. Animals should have free access to it at all times.

The above recommendations are what many successful dairymen now practice, and are within the reach of all who wish to improve their feeding practices in this respect.

NOTE: It is possible that most cows when fresh are in negative calcium balance; that is, they excrete in the milk and manure more calcium than they consume. This condition in all probability is more pronounced and continues for a longer period in case of cows bred for heavy milk production. It has been shown recently by the Wisconsin Station that direct sunlight checks this tendency to a limited extent. Whether the antirachitic vitamin is of pronounced influence in aiding calcium assimilation in case of dairy cows is still an open question.

SKIM MILK POWDERS IN THE REARING OF YOUNG CALVES

By J. B. LINDSEY and J. G. ARCHIBALD

In our studies of substitutes for whole or liquid skim milk in the rearing of young calves, we have tried both the drum dried and the spray dried skim milk powders.

Method of Manufacture of Milk Powders

In the spray process, the liquid milk is forced under high pressure through nozzles into the upper part of a heated chamber. The fine spray is dried to a fine powder by the time it reaches the bottom of the chamber. The chief advantage of this process is that the powder is very readily and completely soluble in water.

In the drum or roller process, the skim milk is fed from a gravity tank onto steam-heated rolls. It spreads out into a thin film, drying as the rolls slowly revolve. The dried film is removed from the rolls by scrapers, ground, sifted and packed. It is somewhat coarser in texture than the spray dried product and does not dissolve in water as readily. The manufacturers claim that the process is not destructive to the vitamins in the milk, especially Vitamin C.

Preparation of Skim Milk Powder for Feeding

One pound of the milk powder and a scant even teaspoonful of salt are added to each gallon of lukewarm water.[1] The milk powder and salt should first be stirred with a small quantity of cold water to avoid lumping, and after a creamy consistency has been secured, the necessary amount of lukewarm water added, the mixture well stirred and thus fed. Enough can be made up, if desired, to last twenty-four hours, but it should not be fed cold.

Method of Feeding

Whole milk was fed for the first week after weaning and then the skim milk solution gradually substituted. Not over nine quarts daily were fed to each calf and it is better, although not necessary, to continue feeding a minimum of two quarts of whole milk daily during the first six or eight weeks of the calf's life. After the first month, the calf was taught to eat rowen and a calf meal made up of 30 pounds red dog flour, 30 pounds ground oats, 15 pounds linseed meal, 24½ pounds of corn meal and ½ pound salt. By the time the calf reached four months of age it was eating one and one-half to two pounds of grain daily and a considerable amount of hay.

The experiment was ended when each calf reached the age of four months at which time the milk was gradually removed and dry feeds substituted. It is preferable, however, in case of promising dairy heifers, to continue giving some of the skim milk until the animals are five or six months of age, in order to promote rapid growth.

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[1] If desired, one pound of the milk powder may be used to 5 quarts of water.

THE RESULTS

Relative Growth, Gains and Costs of Rearing Calves on Skim Milk Powders

Material	Number of Calves*	Average daily gain Lbs.	Dry matter required for 100 pounds gain Lbs.	Food cost per pound of gain Cents
Skim milk powder (drum process)	6	1.50	287.79	16.5
Skim milk powder (spray process)	6	1.39	277.72	22 2
Liquid skim milk for comparison	6	1.68	250.78	14.3

* All grade Holstein calves.

Liquid skim milk was charged at 1½ cents a quart, drum dried powder 7½ cents and spray dried powder 11 cents a pound (drum dried solution, 1.9 and spray dried solution, 2.75 cents a quart). The table shows:

1. That neither skim milk powder promoted as rapid growth as did the liquid skim milk.

2. That the drum process powder produced slightly better growth than did the spray process powder. The difference is not great and too much stress should not be placed upon it. Inasmuch, however, as the drum dried powder may often be purchased for several cents a pound less, it is to be preferred for calf feeding.

3. Dried skim milk offers the best substitute for liquid skim milk in the rearing of young calves. At the present, the price has advanced to 11 cents for the drum dried and 13½ per pound for the spray dried, which renders their use of doubtful economic value. The price will vary according to supply and demand.

BETTER FEED FROM PERMANENT PASTURES

By SIDNEY B. HASKELL

In the spring of 1921 the Massachusetts Experiment Station instituted certain fertilizer experiments on a typical, rock-bound, weed-grown permanent pasture. The pasture must have been last plowed more than 100 years ago, in the days of cheap labor and ox team power. A part of the pasture had once been tilled, had degenerated into pasture, had then grown a crop of wood and timber; and then after many years had been brought back to pasture in a century-long rotation. Of clover and blue grass there were but the scantiest traces. Running cinquefoil and great clumps of green moss had crowded out the better types of vegetation.

It was under these discouraging conditions that the first fertilizer was applied, as a top-dressing, in the early spring of 1921. A second, more elaborate experiment was started in 1922. The fertilizers applied, and the rates at which they were used, were as follows:

Acid phosphate,	480 and 960 pounds per acre.
Muriate of potash,	80 and 160 pounds per acre.
Ground limestone,	2400 pounds per acre.

Acid phosphate and muriate of potash as above, at the two different rates.

Space does not permit of extended description of the remarkable effect of these fertilizers. By 1923 many of the plots had developed a dense growth of white clover. Potash was the most effective of any of the treatments; lime and acid phosphate, used alone or together, were relatively ineffective. Potash and acid phosphate combined, especially when used in the limed areas, showed a distinct advantage over the potash alone. As time has elapsed, the apparent effectiveness of lime has been increasing; also, but to a less marked degree, has that of the acid phosphate.

Photographic records best portray the remarkable results of this experiment. A camera was suspended over a typical area, and in each of three successive years an exposure was made of the same portion of the sod. The upper picture shows the character of the sod as it was before fertilizer was applied; that in the center, taken a year later, shows the changing vegetation as produced by fertilizer; and the lower picture shows the results of 1923, which was definitely a "clover year." The fertilizer here used was the potash and acid phosphate mixture with lime. Similar results were obtained in the experimental plots started in 1922; but here, probably on account of more favorable weather conditions, the fertilizer had more rapid effect.

Effect of Fertilizer on Quality of Pasturage

About the middle of June, 1923, animals were barred for a three weeks period from the pasture plots fertilized in 1922. Samples of the three weeks' growth were cut, the product dried, weighed and subjected to chemical analysis. Results are shown in the following table:

Fertilizer Treatment	Dry Matter per Acre, Pounds	Protein	
		Per cent	Pounds per Acre
Acid phosphate 960 lbs.; no lime	863	14.17	122
Acid phosphate 960 lbs.; limestone 2400 lbs.	1050	18.70	196
Muriate of potash 160 lbs.; no lime	676	20.78	140
Muriate of potash 160 lbs.; limestone 2400 lbs.	1023	23.29	238
No fertilizer; no lime	703	14.60	103
Limestone 2400 lbs.	766	17.97	138
Acid phosphate 960 lbs.; muriate of potash 160 lbs.; no lime	1272	20.56	262
Acid phosphate 960 lbs.; muriate of potash 160 lbs.; limestone 2400 lbs.	1576	24.53	387

The greatly increased yield of protein on the best treated plot is most significant, with a total production equal to that contained in 2400 pounds of wheat bran. The cause of this change is of course the stimulation of clover and the suppression of the weeds brought about by the use of lime and fertilizer.

The Grass Cycle

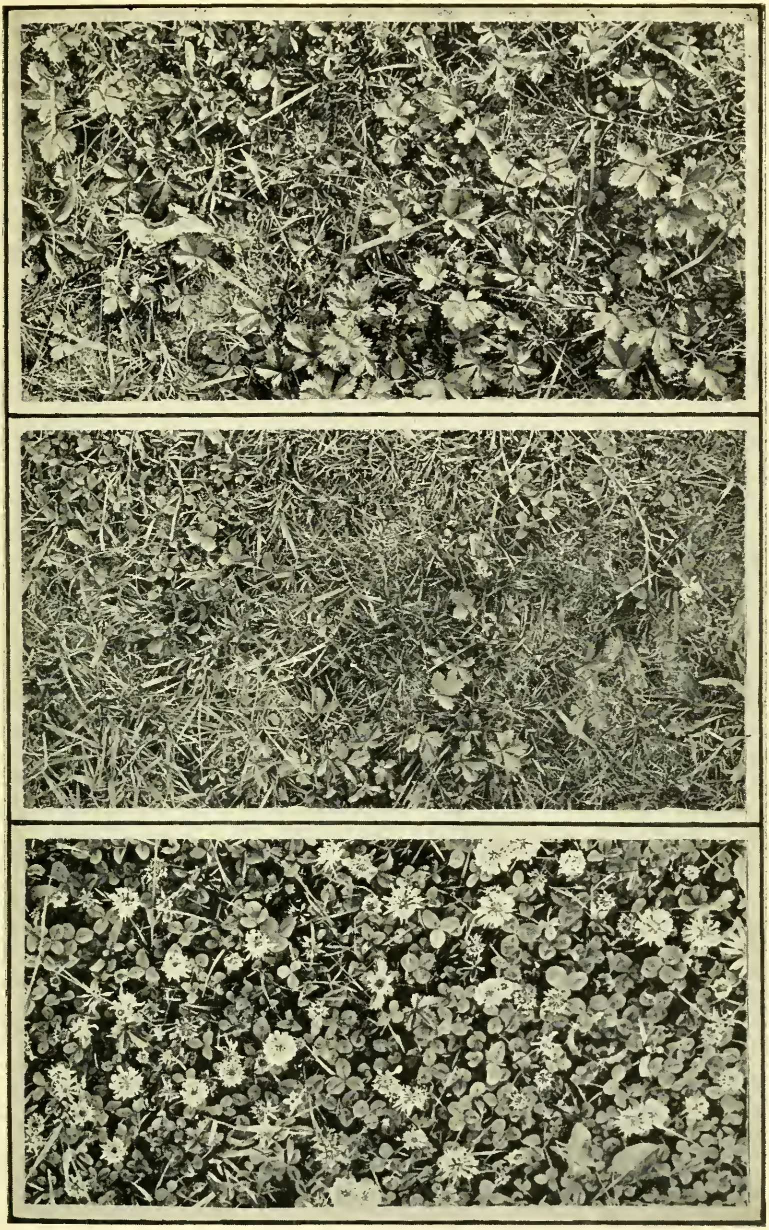
White clover, however, comes and goes. By the fall of 1924 it had disappeared from these plots almost absolutely and been replaced by blue grass. In the spring of 1925 no clover was in evidence, even on those plots which had been densely carpeted in the summer of 1923. In the early summer of 1925, however, drouth conditions prevailed, to be broken during the end of June by generous rains. These conditions favored clover, and by the end of that year it was once more dominant on all of the better fertilized areas.

It is impracticable to translate the above figures into terms of profit and loss. We have no means of knowing how long a time fertilizer will continue to show benefit. Yet the fact that large areas have already reverted to forest shows what must happen to existing pastures in case fertilizer be not applied; or in case the price of milk be too low to make profitable such fertilizer application.

What Fertilizers Are Needed.

On the relatively coarse grained, depleted granitic soils of the Station farm, potash was the plant food most needed. Best growth was obtained with lime. Acid phosphate applied in addition to lime and potash still further bettered the yield. The total expense of application of these three materials was, of course, very heavy. On heavier pasture soils, acid phosphate may be all that is required. In certain demonstrations west of the Connecticut River, instituted by the Department of Agronomy, M. A. C., this is indicated most clearly. It is probable that, where the soil is fairly close grained and has a favorable moisture supply, acid phosphate, with lime if the soil be extremely acid, will be all that is required. These of course must be applied as top dressing, which means that action is certain to be relatively slow.

The fertilizing of pastures is a most interesting field for farm experiments. There are, however, certain discouraging conditions attending it. Returns from fertilizer application are always delayed, for only by stimulating white clover and grass so that it can crowd out the weeds is the better pasture secured. If the weather be dry, there may be a period of weeks or even of months in which there will be no growth on either fertilized or unfertilized portions of the pasture. Even when good growth is produced, as should usually be the case, the fact may not be noticed, for increased forage may be pastured off as rapidly as it is grown. Yet with all of these uncertainties, the goal is worth the effort. A pasture which is in a weedy or run-down condition because of a lack of plant food can be brought back to productive condition only by the use of plant food.



Progressive Change in Pasture Vegetation.
Top—Before Fertilizer was Applied.
Center—One Year after Application.
Bottom—Two Years after Application.

THE UTILIZATION OF FEEDS BY HORSES

By J. B. LINDSEY AND J. G. ARCHIBALD

Although it is recognized that for many industrial purposes the automobile, auto truck and farm tractor have replaced the horse as a source of power, we believe that the horse, for a long time to come, will continue to have his place upon the farm and in certain other lines of industry.

For a number of years studies have been made at this Station of the digestibility, metabolizable energy and net energy of the ordinary roughages, grains and by-products likely to be fed to farm and other work horses in order to ascertain their relative nutritive values.

Units of Measurement.

In order to get at relative nutritive values, we must have one or more units of measurement. Obviously the foot rule or the yardstick would not serve for such a purpose. The best units we have are (a) chemical analysis of the feed, (b) its digestibility, (c) its total, metabolizable and net energy values.

(a) *Chemical analysis* tells how much of each of the several groups, protein, fat, carbohydrate and ash, a feed contains but it does not tell how much of each group the animal can finally utilize.

(b) *Digestibility.* By digestibility is meant the amount of each ingredient the animal can digest or so transform that it can be carried into the blood stream and made use of as food. The solid excreta or feces is the undigested portion of the feed which, subtracted from the total feed, leaves that which is digested. The *digestion coefficient* means simply the *percentage* of the feed or ingredient digested. Thus, if a feed contains 30 per cent or pounds of fiber in 100 pounds and 15 pounds is digested, the coefficient is 50.

(c) *Energy.* Every food may be regarded as a mass of latent energy. Digestion liberates this energy and the animal lives and produces, as a result of the liberation.

Total energy represents all of the energy contained in a feeding-stuff, and is determined by the use of a complicated piece of apparatus known as a bomb calorimeter

Metabolizable energy is the total energy less that contained in the feces and urine.

Net energy is the total energy minus that lost in the feces and urine and that used in the process of digestion and assimilation.

While the determination of digestibility tells us the amount of a food digested, it does not tell the cost to the animal of the energy expended in the digestive processes. Comparative digestibility of feedstuffs, however, is a very helpful unit of measurement, but net energy is the more exact. Unfortunately the present method for determining net energy is very difficult, expensive and time consuming. The only equipment available in the United States for large animals is that at the Institute of Animal Nutrition in Pennsylvania, financed by the National Government. The late Professor Armsby, the director of the institute, as a result of his own experiments and those conducted in Europe, deduced a formula for determining net energy, based upon chemical analysis, total energy and metabolizable energy. In the experiments here reported, we have made use of this formula after having determined the composition and the total and metabolizable energy in each feedstuff, as well as its digestibility; and it is these two units of measurement—*net energy*, expressed in therms[1], with *digestibility* as an aid— that we have used in getting at the relative values of the feeds studied.

METHOD OF PROCEDURE

Two horses were used in each trial. Each feed was analyzed and its total energy determined. Definite amounts daily were fed, the feces and urine collected, and the energy contained in them determined and subtracted from the total energy of the feed, which gives the metabolizable energy. By the application of the formula mentioned above, the net energy was estimated. In the above procedure we were able also to determine digestibility. Each actual experiment required about three weeks for its completion, in addition to a large amount of work in the chemical laboratory and in the calculation of the results.

SOME RESULTS OF THE EXPERIMENT

The Story of Alfalfa.

Two different lots of alfalfa were tested, one grown in New York state and the other on the Experiment Station grounds. The New York sample contained 11.7 per cent protein and 35.2 per cent fiber, while the Station sample contained 17.7 per cent protein and 27.5 per cent fiber. It is evident that the former sample was more mature than the latter.

Average Digestion Coefficients and Net Energy Values

Material	DIGESTION COEFFICIENTS (Per cent)				Net Energy per 100 pounds (Therms)
	Dry Matter	Protein	Fiber	Nitrogen-free Extract	
Alfalfa, New York sample	49	66	34	60	14
Alfalfa, Massachusetts sample	53	73	38	62	36
Alfalfa fed to cattle (for comparison)	58	72	46	66	34

These results indicate that the New York sample was more mature and less utilized by the horses than the Massachusetts sample; while the net energy values show that the horses had to expend considerably more energy to digest the New York, or late-cut sample.

The comparison of the digestibility of alfalfa by horses and cattle, given in the table, shows that cattle are able to digest alfalfa to a greater degree than are horses, although the protein is well and about equally digested by both classes of animals.

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[1] The therm represents the amount of heat required to raise 1000 kilograms of water 1 degree Centigrade, and is used as a unit of measurement for energy.

What the Horses Did with Timothy and Kentucky Blue Grass Hay.

Five of the samples tested were largely Timothy, and contained from 3.86 to 7.68 per cent protein and from 28.9 to 31.7 per cent of fiber. It is evident that some samples were cut earlier than others. One sample was fine in quality, was composed mainly of Kentucky blue grass, and contained 7.70 per cent of protein and 28.35 per cent fiber.

The average digestion coefficients and net energy value are given in the following table:

Average Digestion Coefficients and Net Energy Values

Material	Number of Samples	Digestion Coefficients (Per cent)				Net Energy per 100 pounds (Therms)
		Dry Matter	Protein	Fiber	Nitrogen-free Extract	
Timothy Hay (coarse)	5	47	44	43	53	27
Kentucky Blue Grass (fine)	1	50	58	47	56	33
Timothy Hay fed to cattle (for comparison)	72	55	47	51	62	43

It was found that the total digestibility of the Timothy varied from 40 to 54 per cent, with an average of 47 per cent, and that the digestibility was inversely proportional to the fiber percentage; that is, the higher the percentage of fiber, the lower the digestibility. The net energy varied from 18 to 38 therms per 100 pounds, with an average of 27 therms. The sample containing the highest percentage of fiber, 31.68 per cent, contained but 18 therms of net energy per 100 pounds; while the lot which contained only 28.8 per cent fiber had 38 therms of net energy. The teaching is the same as in the case of alfalfa: namely, that late cutting, high fiber content and low net energy go hand in hand. The conclusion is clear, that the later the hay is cut, the less its nutritive value per pound or ton. Horse feeders prefer late-cut, coarse hay, not for its high nutritive value but because of its distention of the intestinal tract and its less laxative effect. They depend largely upon the grain ration for nutrition, and upon coarse hay as a distributor.

The fine hay was more digestible and had more therms of net energy than the coarse. The average results with cattle show that they are able to make better use of Timothy hay than do horses.

A Kansas Ration v. a Substitute Ration.

The Kansas ration, so-called, was a combination of alfalfa, corn and oats, recommended by the Kansas Experiment Station and the United States Department of Agriculture, who experimented jointly for a period of 140 days with 17 artillery horses, doing what was termed rapid light draft.

The combination which proved satisfactory in the trials cited was recommended on the ground that a relatively small amount of roughage (alfalfa) fed with a relatively large amount of corn and oats would require a minimum of energy for its digestion; and that the alfalfa furnished the necessary amount of protein and was not fed in sufficient amounts to prove injurious.

Inasmuch as alfalfa was but little grown in Massachusetts, we compared the Kansas ration with a substitute ration composed of Timothy hay, corn, oats, bran and dried brewers' grains, the latter furnishing the protein lacking in the Timothy.

The two combinations fed to determine digestibility and net energy requirements were as follows:

	Kansas Ration Lbs.	Substitute Ration Lbs.
Alfalfa	8.25	....
Timothy	—	9.00
Corn	6.60	4.20
Oats	1.65	2.40
Bran	...	1.21
Brewers' grains	—	1.80
Totals	16.50	18.61

Chemical Composition

Ration	Water as Fed (Per cent)	Dry Matter Basis					
		Ash (Per cent)	Protein (Per cent)	Fiber (Per cent)	Nitrogen-free Extract (Per cent)	Fat (Per cent)	Total Energy per 100 pounds (Therms)
Kansas	13.72	4.68	13.66	19.30	58.82	3.55	201.42
Substitute	11.42	4.55	11.91	21.56	58.17	3.80	203.84

In chemical composition one notices little difference except that the Kansas ration is lower in fiber and higher in protein.

Average Digestion Coefficients and Net Energy Values

Ration	Digestion Coefficients (Per cent)					Net Energy per 100 pounds (Therms)
	Dry Matter	Protein	Fiber	Nitrogen-free Extract	Fat	
Kansas	63	78	?	78	54	76
Substitute	53	65	?	64	35	59

The horses in each case digested little fiber and the results are not reported. A study of the digestion coefficients and net energy values shows that the horses made better use of the Kansas ration.

On the basis of 1000 pounds live weight, the horses in the experiments conducted at the Kansas station were fed, daily, 8.5 pounds of alfalfa, 6.8 pounds of corn and 1.7 pounds of oats while doing their work. These amounts seemed to us quite small, and practical experiments with our own horses, as well as comparisons with generally accepted standards, confirmed this conclusion.

As a result of our digestion and energy study, as well as of practical feeding trials, we have concluded that a combination of alfalfa, corn and oats in the proportions indicated above, known as the Kansas ration, proved superior to a combination of Timothy, corn, oats, bran and dried brewers' grains but that the amount of the Kansas ration fed per 1000 pounds live weight should be at least 20 per cent more than recommended by the original experimenters. The Kansas station emphasized the fact that alfalfa, when cut in full bloom and free from mold, smut and excessive dust, is suitable for horses; and that one and one-fifth pounds daily per 100 pounds live weight is the maximum amount to be fed to work horses.

Trials with the Cereals.

Experiments were made with whole corn, cornmeal, corn cobs, oats and oat hulls. Their chemical composition and total energy value are stated in the following table. For the sake of comparison the analyses are all stated on a dry matter (water free) basis.

Chemical Composition

Material	Water as Fed (Per cent)	DRY MATTER BASIS					
		Ash (Per cent)	Protein (Per cent)	Fiber (Per cent)	Nitrogen-free Extract (Per cent)	Fat (Per cent)	Total Energy per 100 pounds (Therms)
Corn meal	16.81	1.54	10.09	2.59	82.13	3.65	203.67
Corn, whole	13.40	1.38	9.88	3.05	81.58	4.13	199.58
Corn cobs	18.67	1.70	3.14	30.23	64.22	0.72	205.48
Oats, whole	10.97	3.35	13.38	10.39	67.56	5.32	207.75
Oat hulls	8.57	6.59	2.52	33.04	56.83	1.02	197.32

The cereals have about the same type of chemical composition; that is, they are relatively low in protein and high in carbohydrate or starchy matter. Oats contain more protein and fat and decidedly more fiber than corn. Corn cobs and oat hulls are quite deficient in protein and fat and are made up largely of fiber and of complex carbohydrates.

The results given below represent the averages secured with two horses.

Average Digestion Coefficients and Net Energy Values

Material	Digestion Coefficients (Per cent)					Net Energy per 100 pounds (Therms)
	Dry Matter	Protein	Fiber	Nitrogen-free Extract	Fat	
Corn meal	72	71	None	85	62	117
Corn, whole	74	62	None	85	51	113
Corn cobs	25	None	None	45	None	None
Oats, whole	61	75	None	72	57	118
Oat hulls	22	?	?	10	82	None

A little study of the figures in the table shows that the two horses digested the whole corn and corn meal in equal amounts and derived about the same net energy from them. One would suppose that corn meal would yield rather more net energy than whole corn because of the energy required for chewing the latter; but our method of measurement was not sufficiently sharp to detect the difference. Although the horses were able to digest 25 per cent of the corn cobs, they did not derive any net energy from them, all the energy being required for the efforts of digestion; hence we may conclude that the cob is without food value for horses.

Oats were not as well digested as corn, due to the presence of about 30 per cent of hulls, which were not digested by the horses in the present trial. Strange to say, the oats furnished fully as much net energy as the corn, namely 118 therms. This result is not confirmed by the few trials on record, which show 93 therms. A further study of the comparative net energy values of corn and oats for horses is desirable. Oat hulls were digested to about the same extent by horses as were corn cobs, and did not furnish any net energy. They are, therefore, without value as a source of nutrition for horses. The nutritive value of the oat for horses is contained in the groat.

Wheat Bran and Brewers' Dried Grains.

These materials are well known to all feeders. The question is often raised as to the value of wheat bran as a horse feed. Brewers' grains, both wet and dried, have been used with apparent success by many feeders of horses. The average chemical composition of the samples tested is stated below.

Chemical Composition

Material	Water as Fed (Per cent)	Dry Matter Basis					
		Ash (Per cent)	Protein (Per cent)	Fiber (Per cent)	Nitrogen-free Extract (Per cent)	Fat (Per cent)	Total Energy per 100 pounds (Therms)
Wheat bran	11.74	7.25	16.79	10.95	59.86	5.16	202.65
Brewers' grains . .	7.68	3.35	28.79	15.59	45.33	6.26	229.30

Both feeds contain a considerable amount of fiber. The brewers' grains are rich in protein and fat, the latter ingredient giving this feed its extra energy value.

Average Digestion Coefficients and Net Energy Values

Material	DIGESTION COEFFICIENTS (Per cent)					Net Energy per 100 pounds (Therms)
	Dry Matter	Protein	Fiber	Nitrogen-free Extract	Fat	
Wheat bran	52	83	None	61	None	52
Brewers' grains	51	77	27	50	46	?

The *average* digestion cofficients for the two feeds do not differ very much. The horses were able to digest about one-half of the entire dry matter, as against 62 and 66 per cent by bovines. The protein was well digested but the animals were unable to make much use of the fiber. The utilization of the fat in the present experiments seemed uncertain.

The ten single trials with wheat bran gave rather wide variations in coefficients as well as in net energy values which indicated that the horses experienced difficulty in making use of it. We are, therefore, led to conclude that as a source of nutrition, it is not to be recommended. It may be fed in limited amounts (1-2 pounds daily) as a component of a ration because of its gentle laxative effect.

The four digestion trials with brewers' grains gave reasonably uniform results. It was quite evident that the horses could digest the protein easily but had difficulty with the fiber. The variations in net energy value are so great that the average result is not stated. The reason for this is not apparent. While in many cases, depending upon local conditions and cost, brewers' dried grains may prove satisfactory as a component of the horse ration, it is believed they can be used to better advantage as a food for dairy stock.

The Utilization of Cottonseed Meal.

Two different lots were fed, testing as follows:

Chemical Composition

Material	Water as Fed (Per cent)	DRY MATTER BASIS					
		Ash (Per cent)	Protein (Per cent)	Fiber (Per cent)	Nitrogen-free Extract (Per cent)	Fat (Per cent)	Total Energy per 100 pounds (Therms)
Cottonseed meal, Lot I	7.62	7.10	37.51	19.69	28.04	7.66	224.53
Cottonseed meal, Lot II	8.76	6.68	41.27	12.79	31.22	8.01	225.44

The first lot of cottonseed meal was inferior to the second lot. It is evident that extra cottonseed hulls had been added to it, increasing the fiber to 19.69 per cent, much above the normal.

Digestion Coefficients and Net Energy Values

Material and Horse	Digestion Coefficients (Per cent)					Net Energy per 100 pounds (Therms)
	Dry Matter	Protein	Fiber	Nitrogen-free Extract	Fat	
Cottonseed meal Lot I						
Joe	61	84	23	71	90	61
Chub	71	89	65	58	100	87
Cottonseed meal Lot II						
Joe	62	87	38	36	87	73
Chub	69	84	19	62	93	104

It is hardly fair to average the two lots of meal, as one contains so much more fiber or hulls than the other. The horse Joe did not utilize the meal as well as did Chub. Both horses made excellent use of the protein and fat but failed to digest the fiber fully. Joe did not secure as much net energy as did Chub. It would be expected that Lot II, containing less fiber, would yield more net energy than Lot I, and such proved to be the case. On the basis of our results, exact figures for net energy cannot be deduced. It is believed that the data secured with Chub are more reliable than those secured with Joe. On this supposition it may be assumed that the therms of net energy in 100 pounds of cottonseed meal will be from 87 to 104. Much, however, depends upon the percentages of fiber and fat contained in the meal.

Our trials show that horses are able to digest cottonseed meal fairly well, especially the protein and fat; and that a liberal amount of energy was derived from its use,—nearly as much as from corn. Its chief use for the horse would be as a source of protein, especially for hard-worked horses, to the extent of from 5 to 10 per cent of the grain ration.

A Word About Linseed Meal.

Two experiments were carried out with this meal, but some of the results were so uncertain that they are not presented. The protein was quite as well digested as that contained in the cottonseed meal. The results for net energy varied widely. The writer would assume, however, that it would not vary greatly from those secured for cottonseed meal. Earlier feeding trials with linseed meal mixed with whole corn and oats, to the extent of 20 per cent, indicated that it did not mix evenly with uncrushed feeds. Horses do not care for it if fed unmixed, but will eat a reasonable amount readily if it constitutes part of a mixture. The addition of 5 to 10 per cent of linseed meal to a grain ration of one or more cereals will furnish the extra protein needed by hard-worked horses and will be eaten without trouble.

Percentage Energy Efficiency of Feeds for Horses.

The total energy contained in all feeds tested, expressed in therms, was 205.46 with extremes of 191 and 229, the latter figure being obtained from brewers' grains which contained considerable fat. The therms of total energy per 100 pounds of dry matter, for most cattle feeds, will not vary much from 200, except for those having more than the ordinary amount of fat.

The percentage of energy utilized—net energy—varied widely, from zero in case of corn cobs and oat hulls to 57 in case of corn. Two samples of alfalfa showed extremes of from 7 to 18 per cent of energy utilized, with an average of 13; six samples of Timothy hay from 9 to 19, with an average of 14. The amount of net energy and the percentage of energy utilized in coarse feeds depends evidently upon stage of growth. Corn was 57 per cent utilized, oats 57 per cent, cottonseed meal 36 per cent, and wheat bran 26 per cent.

We fail to find on record data of the utilization of energy of individual feeds by horses. It can be said, however, in general, that the less the percentage of crude fiber, and in roughages the less mature the material, the greater will be the energy available. Armsby has computed the availability of the energy for ruminants as varying between 5 and 24 per cent for roughages, 46 per cent for corn and hominy meals, and 29 per cent for wheat bran.

Summary

The results of the feeding trials with horses, reported in the preceding pages, may be summarized as follows:

Timothy hay and alfalfa had about the same net energy value, but different samples varied widely, depending upon the stage of growth.

Corn cobs and oat hulls were without net energy value.

The cereal grains had substantially the same net energy values—somewhat more than did the high-grade nitrogenous concentrates such as cottonseed and linseed meals.

Wheat bran had a low energy value and as a source of nutrition proved inferior to other concentrates fed.

The protein in dried brewers' grains was well utilized, but the results for net energy were uncertain. This material is recommended more as a feed for dairy stock than for horses.

Cottonseed and linseed meals have quite high net energy values and their protein is well utilized. They may serve in limited amounts (1 to 2 pounds daily) as a supplement to the grain ration for hard-worked horses.

The percentage energy utilization varied from 57 per cent in case of corn to zero in case of corn cobs and oat hulls; the energy in timothy hay and alfalfa hay was utilized to the extent of from 7 to 19 per cent with an average of 14 per cent.

The net energy value of feeds depends to a considerable extent upon the percentage of crude fiber present—the higher the percentage of fiber, the less the net energy and *vice versa.* In case of coarse feeds, the later the stage of growth and hence the more mature the material, the less its net energy value.

The *character* of fiber influences its digestibility and net energy value. Fiber in straw and oat hulls is less digestible than in corn bran and in early cut hay. The more mature a plant, the more woody the tissue becomes, with an increasingly lessened digestibility.

IMPROVING THE FEEDING VALUE OF GRAIN HULLS AND SAWDUST

By J. G. ARCHIBALD

Foreword

A great deal of study has been devoted by numerous investigators in different countries to improving the digestibility and consequently the feeding value of straws and other fibrous or woody materials. Straw of various kinds is only from 46 to 52 per cent digestible, oat hulls scarcely 40 per cent and cottonseed hulls 53 per cent digestible, while rice hulls, flax shives and sawdust show little if any digestibility. Furthermore, so much energy is required in the digestive processes that these materials, in their natural state, have but little net energy or actual nutritive value. Attempts to improve the feeding value by fine grinding, soaking in water and steaming under pressure have proved to be useless; so also has mixing the fine material with such a palatable substance as molasses.

The straws have also been treated with various chemicals such as dilute sulfuric and hydrochloric acids, lime in the form of the sulfide and oxide, sodium carbonate and sodium hydrate, both by boiling in open kettles and under pressure. Many of these methods have greatly improved the feeding value of the straws.

Why Wood, Straws, Grain Hulls and Similar Fibrous Materials Have Low Feeding Values.

Plant fibers (crude cellulose) are an aggregation of cell walls of certain specialized cells occurring in the plant. These cell walls become elaborated, enlarged and strengthened with age until maturity is reached, at which time, in high fiber plants at least, they constitute the major portion of the individual cells, the cell contents or protoplasm having been almost, if not altogether, absorbed or transported to the seeds.

In the early stages of growth, the cell wall consists of pure cellulose and hemi-cellulose and is soft and reasonably well digested, but as growth proceeds and maturity is reached, it becomes changed to a compound known as ligno-cellulose and the process is known as lignification. This ligno-cellulose complex cannot be digested to any extent because the digestive fluids cannot penetrate it. Some silicic acid also incrusts the complex and still further hinders the action of the digestive fluids and micro-organisms. The action of chemicals, particularly the alkalies, dissolves out the silicic acid and also breaks the bonds holding the cellulose and lignin together, and the cellulose thus set free can be acted upon and converted into nutritive material. As a result of the process, the lignin is more or less decomposed but is of little, if any, nutritive value.

WORK AT THE MASSACHUSETTS STATION.

Experiments with Oat, Barley, Cottonseed and Rice Hulls and Flax Shives. The normal output of oat hulls by three of the leading oat-milling concerns in the United States has been estimated at over 100,000 tons. Data are not available for the other materials. Ground cottonseed hulls are added in limited amounts to cottonseed meal, and are also fed extensively in the South, unground and mixed with one-quarter their weight of cottonseed meal. Formerly, if not now, they were used as fuel in the cottonseed mills. Rice hulls and flax shives, ground fine, have been used in low-grade feeding stuffs or discarded by millers and farmers.

Any method which would bring about an increased digestibility of these, and similar by-products, was considered worthy of investigation. Aside also from the possible practical results, it was felt that the facts likely to be brought out would be of considerable scientific significance and open the way for further study.

Method Employed.

Originality is not claimed for the method used. It was devised by Dr. Ernst Beckman and employed by him and others during the World War for improving the value of different straws. Briefly stated, the method consisted in treating the hulls for three hours, with frequent stirring, with eight times their weight of dilute sodium hydrate (1.0, 1.5 or 3 per cent) after which the darkened soda liquor was allowed to drain off and the hulls thoroughly washed with cold water and dried.

Chemical Composition of the Untreated Hulls.

Material	Water as fed	DRY MATTER (Per cent)				
		Ash	Crude protein	Crude fiber	Nitrogen-free extract	Crude fat
Oat hulls	7.70	6.33	2.26	33.24	57.24	0.93
Cottonseed hulls	6.93	2.13	4.08	43.99	48.60	1.19
Rice hulls	6.25	19.06	3.02	41.80	35.38	0.75
Flax shives	6.78	4.09	5.24	53.81	35.05	1.81

The analyses show the several substances to be quite low in protein and fat and high in fiber. The cottonseed and rice hulls, and particularly the flax shives, are very fibrous in character. The character of the fiber governs to an extent digestibility, depending upon the exact nature of the linkage between the cellulose and lignin and possibly upon the chemical nature of the lignin.

The Action of the Soda (Sodium Hydrate) on the Hulls.

The above materials were treated with dilute sodium hydrate (1.5 per cent), as already described. The chemical dissolved out a little of the protein and fat and more of the nitrogen-free extract, the total losses varying from 10 pounds, in case of the cottonseed hulls, to 25 pounds, in case of the flax shives, for each 100 pounds of dry material treated. The nitrogen-free extract lost consisted principally of pentosans, substances similar to starch and cellulose.

Digestibility of the Treated Materials

After the treatment had been completed and the materials dried, experiments were carried out with sheep to determine digestibility.[1]

Summary of Digestion Coefficients.

	Total Dry Matter	Crude Fiber	Nitrogen-free Extract
Oat Hulls, untreated	36	52	34
Oat Hulls, treated	81	91	79
Percentage increase	**122**	**73**	**132**
Cottonseed Hulls, untreated	53	58	59
Cottonseed Hulls, treated	55	53	68
Percentage increase	**3**	**—10**	**15**
Rice Hulls, untreated	very little	very little	very little
Rice Hulls, treated	29	28	38
Flax Shives, untreated	0-30	0-19	4-33
Flax Shives, treated	29	23	38

The results in the above table represent the average for two sheep. The action of the soda solution is reported on the total material, designated as total dry matter, and on the crude fiber and nitrogen-free extract matter. The other ingredients (protein and fat) were present in such small amounts as to be without practical significance.

It is clear that the digestibility of the oat hulls as a whole (total dry matter) was very much improved, and the same can be said for the fiber and extract matter. The cottonseed hulls were not improved by the treatment. The sheep were not able to digest the untreated rice hulls to any appreciable extent, but did digest the treated hulls somewhat. The increase in digestibility was not sufficient to render the treated product of any practical value. The same can be said of the flax shives.[2]

On the basis of water free material (dry matter), after making an allowance for losses due to treatment, a ton of oat hulls was increased in digestibility from 725 pounds to 1345 pounds, the digestibility of the crude fiber from 349 to 732 pounds, and the nitrogen-free extract from 390 to 622 pounds.

It is evident, therefore, that as a result of chemical treatment,[3] a marked increase in nutritive value of the oat hulls has been secured and that such treatment would be of service in case of a pronounced shortage of cattle feed. Further study is warranted, in order to devise a method that will decrease the cost of treatment so that such materials could be handled economically in large amounts.

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[1] For description of method, see Mass. State Agr. Expt. Sta. Rept. 11, pp. 146-149, 1893; also Mass. Agri. Expt. Sta. Bul. 181.

[2] Barley hulls were also tested but they contained so much of the barley meal as to render the results valueless.

[3] A fuller report of these studies has been given in the Journal of Agricultural Research, Vol. XXVII, No. 5.

Work with Sawdust.

Sawdust from various woods has been proved to be without value as a food for domestic animals. Numerous investigations have been made and patents issued for the conversion of this inert material into a cattle food. The method of procedure in most cases has been the treatment of the sawdust with dilute mineral acids under pressure, or treatment with alternate portions of acid and alkali. These processes have resulted in converting more or less of the cellulose and hemi-celluloses into sugars. The cattle foods thus manufactured have not met with any extensive use, and so far as we are aware, are not at present on the market. Some time ago, the Forest Products Laboratory of the United States Department of Agriculture, located at Madison, Wisconsin, carried on extensive investigations in the conversion of the sawdust from several species of wood into more soluble forms, for the production of industrial alcohol and as a possible source of cattle food. The Forest Products Laboratory asked that the Massachusetts Experiment Station cooperate in making a study of the feeding value of the product. The material was prepared by them and shipped to this Station for study.

Method of Preparation.

The treatment consists in cooking the sawdust under 120 pounds pressure with dilute sulfuric acid (1.8 per cent) which converts a portion of the cellulose and allied substances into sugar. The liquor resulting from this treatment, together with water used in washing the residue, is neutralized with lime, and evaporated under reduced pressure to a thick syrup and then mixed with the previously dried residue. The product when ready for feeding is a dark brown, somewhat powdery meal, with a slight woody odor and a sweetish woody flavor. The materials sent were prepared from the sawdust of Douglas fir and white pine.

The work at this station consisted in the making of numerous analyses of the products, noting their palatability with dairy animals, determining their digestibility and noting their feeding value for milk production. We present below the results secured.

1. The treated or prepared sawdust is composed of crude cellulose and lignin together with some 28 per cent of sugars.

2. Animals will not eat the treated sawdust when fed by itself. In order to promote consumption it is necessary to mix it with other grains. Occasionally an animal will refuse to eat the mixture of which the sawdust is a component.

3. About 4 pounds daily is all that the mature dairy cow will consume, especially if it is fed for any length of time.

4. Digestion studies show that the dry matter of the Eastern white pine sawdust was about 46 per cent digestible, while that of the Douglas fir sawdust was about 33 per cent digestible. In the case of the Douglas fir sawdust, digestion was confined principally to the sugar formed by the treatment, while in the case of the white pine sawdust apparently some of the cellulose was digested also.

5. If the process of treatment could be modified so as to convert a larger proportion of the cellulose of the wood into sugar, or more completely separate the cellulose from the lignin, the food value of the material would be enhanced.

6. On the basis of equal amounts of digestible nutrients the sawdust when fed to dairy cows produced only slightly smaller amounts of milk than did corn starch, but it took, on an average, 2.75 pounds of sawdust to equal one pound of starch. The cows fed on the treated sawdust ration produced rather less milk, shown more in their milk yield at the beginning of the experiment, and gained less in body weight, on the treated sawdust than on the starch ration, all of which is indicative of the fact that, on the basis of equal amounts of digested matter, the treated sawdust was inferior to the starch.

7. On the basis of the present supply and cost of carbohydrate concentrates it is believed that the product as now prepared has no economic value. Under unusual conditions, as in the case of an extreme shortage of ordinary feedstuffs, it might be used as a partial substitute for the cereal grains or starchy by-products.

4,000. 5-'26. Order 5317.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 231 JANUARY, 1927

THE MARKET OUTLET FOR MASSACHUSETTS APPLES

By LORIAN P. JEFFERSON

With the certainty that the southern New England apple crop will be greatly increased in size, perhaps even doubled, within the next ten years, the need of new outlets for the crop is evident. Massachusetts now produces two-fifths of the commercial apples grown in New England; any market stagnation due to failure to find an outlet must inevitably affect Massachusetts producers. This study, therefore, was undertaken for the purpose of finding first, where New England apples are now sold, and secondly, those sections which now receive less than they could apparently easily consume. This study of the foreign and domestic market for the New England apple is supplemented by a study of prices and of methods and cost of export.

Requests for bulletins should be addressed to

AGRICULTURAL EXPERIMENT STATION,
AMHERST, MASS.

THE MARKET OUTLET FOR MASSACHUSETTS APPLES

By Lorian P. Jefferson

This monograph is part of the general study of the economic aspects of the New England apple industry undertaken by the Massachusetts Experiment Station. It was arranged in order to determine the competitive position of Massachusetts and New England apples in both domestic and foreign markets; to analyze the factors which limit the demand; and to determine, insofar as possible, the measures by which the market may be improved.

Methods

The information presented was secured by personal interview from wholesalers, both exporters and those dealing on the domestic market only, and from retailers. Consumers were reached by questionnaires. Some were sent by mail, some were secured through the cooperation of public school teachers. The questionnaires were distributed to certain pupils who took them home, filled them out with the assistance of their parents, and returned them to the teacher. Some were obtained through women's clubs under the supervision of the home demonstration agent of Hampden County.

In retail stores are included chain stores, fruit stands, self-service and individual stores. From each was secured information as to volume of apples handled in a year, sources from which purchased, whether home-grown or Western apples were handled, varieties preferred, quantities usually sold, advertising, nationality and occupation of body of customers. In addition, the investigator formed his own estimate as to the grade of custom, whether the store handled cheap, medium or first grade products.

The location and character of these stores is shown in the following table.

Table 1.—Types of Stores

City	Self-Service	Chain	Individual	Total
Boston	5	8	48	**61**
Brockton	1	16	13	**30**
Lowell	1	0	8	**9**
New Bedford	1	2	5	**8**
Springfield	1	2	32	**35**
Worcester	0	45	74	**119**
Miscellaneous	0	6	3	**9**
Total	**9**	**79**	**183**	**271**

While the self-service stores may be either chain or individual stores, because of their peculiar character they are classed separately. The few visited in connection with this study were all reported as individual stores.

Classified on the basis of type of trade—cheap, medium and exclusive —67 of the stores are ranked as cheap, 204 as medium and 59 as exclusive. Obviously there is considerable overlapping, many stores catering to more than one grade of custom.

The table below shows the exact classification of the 266 stores for which estimates were given.

TABLE 2.—Stores Reporting Grades of Trade

Cheap	35
Cheap and Medium	10
Medium	162
Medium and Exclusive	11
Exclusive	26
Cheap and Exclusive	1
All Grades	21

The consumer schedules, about 500 in number, were obtained from all classes insofar as possible[1]. According to the occupations of the head of the family, those reporting were classified into labor, business, professional, agricultural, public service and housekeeping groups. The labor class comprised 47 per cent of all those reporting and included factory employes, mechanics, and general laborers. The business group was 24 per cent of the total number; professional people made up 17 per cent. Those engaged in some form of agricultural work were 6 per cent of the whole number. The remainder is evenly divided between public servants and housekeepers, themselves the heads of their households.

No general differences in type of demand are apparent between classes as such. Differences between localities and differences between nationalities are more or less apparent.

The author wishes here to acknowledge her indebtedness to the many informants who have given so generously of time and thought to the problems herein presented. Without their aid this study would have been impossible.

The Division of Markets of the Massachusetts Department of Agriculture cooperated in the collection of information, loaning the assistance of three agents of the bureau for the purpose. The Federal Bureau of Agricultural Economics, through its Boston office, also contributed certain expenses incidental to this study.

Acknowledgment is made of the assistance of Mr. Jesse W. Tapp, of the United States Department of Agriculture and the New England Research Council, who placed at the disposal of the author a large amount of data on the prices of apples, and certain charts on that subject presented herewith.

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[1] While the numbers of retailers and of consumers are comparatively small, much thought was given to the problem of selection and it is believed that the schedules obtained from each group are as thoroughly representative as possible.

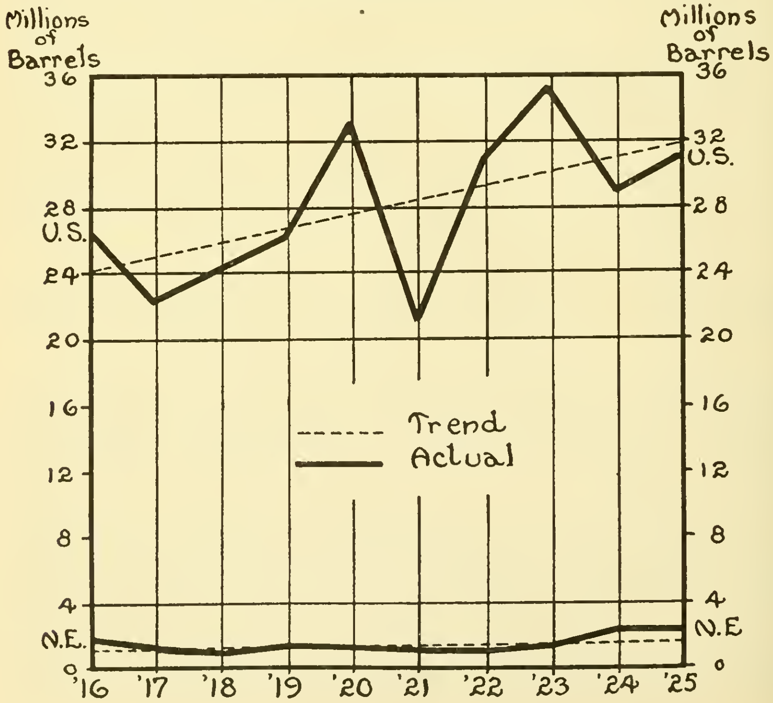
THE DOMESTIC MARKET

The Crop

While total apple production in New England shows little change during the decade from 1916 to 1925, the trend of the commercial crop is slightly upward. The commercial crop in Massachusetts, however, shows an increase of 65 per cent in volume during the same period. More striking is the fact that the three-year-average, 1923-1925, shows an increase of 114 per cent over the average of the first three years of the decade. The total crop in New York shows a slight upward tendency during this 10-year period, but there is little change in the trend of the commercial crop.

The commercial crop of Washington has increased more rapidly than that of any other section, showing an increase of 70 per cent from 1916 to 1925. The accompanying chart shows the actual fluctuations and the trend of both the New England and the United States crops for these ten seasons. (Chart 1). The increase in both volume and trend of the United States crop is much greater than of the New England crop, which indicates that the competition which the New England crop must meet is steadily increasing.

CHART 1. Volume and Trend of Commercial Apple Production in the United States and New England, 1916-1925



Competition of New England Apples

In Table 3 are shown the volume of the commercial crops in New England, Massachusetts, and their greatest competitors, New York and Washington, 1916 to 1926.

Table 3.—Commercial Apple Crop of New England, Massachusetts, New York and Washington, 1916-1926 (barrels)

Year	New England	Massachusetts	New York	Washington
1916	1,663,000	368,000	5,544,000	4,882,000
1917	992,000	225,000	2,058,000	4,620,000
1918	881,000	300,000	5,950,000	4,296,000
1919	1,584,000	335,000	2,975,000	7,167,000
1920	1,255,000	375,000	6,500,000	5,734,000
1921	1,133,000	172,000	3,300,000	8,300,000
1922	1,068,000	461,000	6,000,000	7,341,000
1923	1,599,000	600,000	4,200,000	9,600,000
1924	2,087,000	675,000	3,738,000	6,275,000
1925	2,064,000	655,000	6,250,000	8,570,000
1926 *a*	2,110,000	880,000	7,032,000	8,500,000

a. Estimates of United States Dept. of Agriculture, Nov. 1, 1926.

In Table 4 are shown unloads of apples in 1925 in 17 large markets of the United States outside of New England. It will be noted that the Northwest supplies the largest proportion of apples in these markets, while New York stands second. New England contributes barely 2 per cent of the total and 8 of the markets receive no New England apples. Twenty-two cities of 34 outside New England, reported by the United States Department of Agriculture, received no apples from New England, and in the

Table 4.—Carlot Unloads of Apples in Selected Markets, by Sources, 1925

Market (city)	Source					
	New England	New York	Middle Atlantic *a*	Northwest *b*	Other	**Total**
Atlanta	0	21	159	191	164	**535**
Baltimore	17	247	156	197	125	**742**
Chicago	60	968	40	3,123	3,583	**7,774**
Cincinnati	23	531	163	306	272	**1,295**
Cleveland	4	788	106	511	161	**1,570**
Dallas	0	0	0	247	217	**464**
Detroit	0	258	171	921	776	**2,126**
Fort Worth	0	0	0	239	127	**366**
Kansas City	0	3	0	835	583	**1,421**
Louisville	5	237	77	198	342	**859**
Minneapolis	0	65	2	191	615	**873**
New York	550	6,611	1,517	4,589	494	**13,761**
Omaha	0	19	0	463	285	**767**
Philadelphia	19	630	665	978	218	**2,510**
Pittsburgh	34	1,454	370	573	139	**2,570**
St. Louis	0	54	57	362	1,477	**1,950**
Washington	0	54	273	188	42	**557**
Total	**712**	**11,940**	**3,756**	**14,112**	**9,620**	**40,140**
Per cent of Total	*2*	*30*	*9*	*35*	*24*	*100*

a. Middle Atlantic includes Delaware, New Jersey, Maryland, Virginia and West Virginia.
b. Northwest includes Idaho, Washington and Oregon.

remaining 12 but 2 per cent of the supply during this year was from this source.

These figures show a comparatively narrow distribution of New England apples. Outside New England and New York they comprise so small a volume of apples unloaded as to be negligible. Apples from New York were distributed to 15 of the 17 markets here listed, and the Northwest shipped apples to each of the markets. Of apples shipped from New England in 1925-26, 51 per cent were sent to New York, 13 per cent to Chicago and 3 per cent to Cincinnati. Other markets received even smaller proportions.

On the other hand, arrivals of New England apples on the Boston market comprised about 44 per cent of the total receipts for the seasons 1920-1924. About 15 per cent were from New York and 22 per cent from Washington. The trend of these receipts is shown in Table 5, which gives

TABLE 5.—Monthly Carlot Arrivals on Boston Market from Chief Sources, 1920-21 to 1924-25

MASSACHUSETTS

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1920—21	0	82	129	167	166	72	46	30	205	18	5	0	**920**
1921—22	9	40	42	49	17	14	7	25	6	0	0	0	**209**
1922—23	46	211	208	260	165	79	55	43	47	34	7	0	**1155**
1923—24	0	130	192	222	165	72	82	91	90	69	23	4	**1140**
1924—25	0	112	233	275	165	101	67	88	85	65	26	0	**1217**
Average	**11**	**115**	**161**	**194**	**136**	**67**	**51**	**55**	**87**	**37**	**12**	**1**	**928**

OTHER NEW ENGLAND STATES

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1920—21	0	0	8	20	34	20	14	13	16	5	6	0	**136**
1921—22	0	20	121	265	223	40	13	11	21	16	9	1	**760**
1922—23	0	2	9	72	40	8	6	9	6	10	7	1	**170**
1923—24	0	2	16	102	75	17	18	18	13	14	4	0	**279**
1924—25	0	0	18	85	126	35	31	25	22	20	4	0	**366**
Average	**0**	**5**	**34**	**109**	**100**	**24**	**16**	**15**	**15**	**13**	**6**	**0**	**341**

NEW YORK STATE

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1920—21	0	29	66	84	121	55	66	42	73	32	25	7	**600**
1921—22	19	64	34	58	15	11	7	21	46	59	18	0	**352**
1922—23	0	0	72	184	108	29	36	24	55	37	40	5	**590**
1923—24	1	7	32	16	8	11	21	21	26	50	81	37	**311**
1924—25	1	6	14	14	2	0	1	1	9	15	28	9	**100**
Average	**4**	**21**	**43**	**71**	**51**	**21**	**26**	**22**	**42**	**39**	**38**	**12**	**391**

WASHINGTON STATE

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1920—21	0	2	1	56	122	49	42	31	75	56	86	13	**534**
1921—22	15	0	19	138	173	58	49	74	102	53	24	24	**629**
1922—23	0	0	0	65	89	91	169	114	80	50	29	3	**690**
1923—24	0	9	14	182	114	96	121	121	64	100	61	32	**994**
1924—25	1	0	10	30	55	84	13	40	19	24	34	16	**326**
Average	**3**	**2**	**9**	**94**	**110**	**76**	**79**	**76**	**68**	**57**	**47**	**18**	**635**

volumes arriving monthly from Massachusetts, other New England States, New York and Washington. New England apples comprised 39 per cent of total receipts during the first two seasons, but 57 per cent of the total during the last two seasons.

Apples from all producing sections are received in larger or smaller quantities on most of the markets of the state. In some of the smaller cities, such as Greenfield, Westfield, Fitchburg, Newburyport, Athol, Gardner, etc., local apples are largely used as long as the supply lasts. Westfield and Greenfield are almost wholly supplied by local apples. Pittsfield, in the early part of the season, uses only apples grown nearby, but most of these are brought over from New York State, and peddled from store to store by the growers. Later in the season, when the condition of the roads does not permit this, and when the weather has grown so cold that apples are not longer safe in ordinary farm storage, the wholesalers supply the retail stores. They also deal more or less in native apples, but handle considerable quantities of Western apples.

North Adams is supplied by New York, Vermont and Massachusetts, with apples from western New York and the Northwest in the latter part of the season.

New Bedford and Fall River are markets for many local apples, but receive more from other sources, much of the local supply being of poor quality, poorly prepared for market. However, the young orchards of the vicinity are commercial orchards which receive good care and the fruit now being offered from them is of good quality, well graded and well packed.

The approximate periods when the different varieties of apples from the various sources are on the Boston market are presented in the accompanying chart, Chart 2. It shows that the chief competition of our early apples is from the Middle Atlantic states, while New York and Washington apples compete chiefly with our late fall and winter fruit.

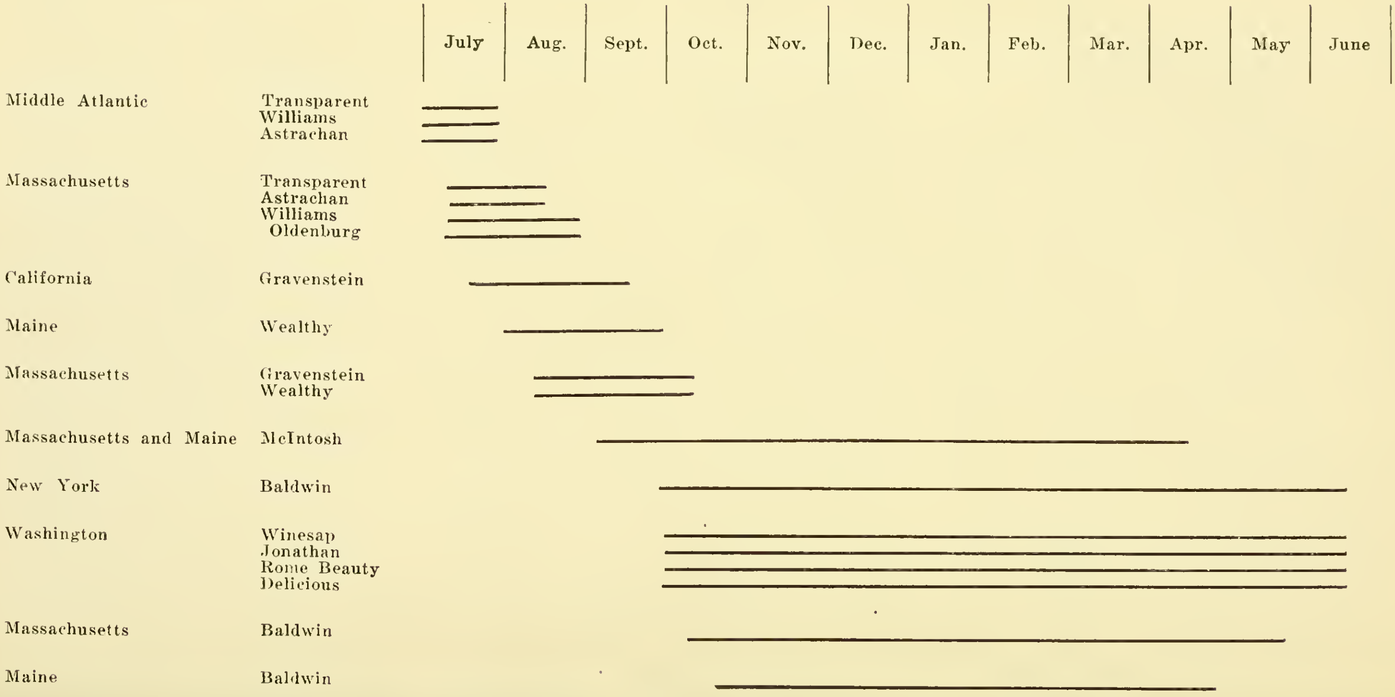
Competition of Massachusetts apples with those from other New England states is not serious. Apples from New Hampshire are of about the same varieties and quality as those grown in Massachusetts. Some dealers believe that the New Hampshire fruit has greater keeping quality, and a few think it takes on better color. On the Boston market Maine apples do not bring the prices that are paid for apples from the other parts of New England.

Other Fruits.

Throughout the year bananas and oranges are the strongest competitors of apples. Bananas arrive on the Boston market in nearly three times the volume of apples, and the average arrivals of oranges are about 45 per cent greater than arrivals of apples. The following tabulation (Table 6) shows carlot arrivals of various fruits in Boston for the 5 years, 1921-1925. During these five years apples have comprised an average of 10 per cent of the arrivals of all fruits on the Boston market.

The latter part of the season apples must meet the competition of strawberries which are on the Boston market from January to July or August, depending on the season, but which reach the peak in May or June. Of course this is a less serious competition than that of peaches and cantaloupes which are in heaviest receipts during June, July and August, although peaches are on the market till October and cantaloupes till December.

CHART 2. Approximate Dates when Apples from Different Sources are on the Boston Market.



The volume of pears received in Boston is much less than those of the other fruits mentioned, but beginning in July they come into competition with the summer, fall and winter apples, remaining on the market until January or later.

TABLE 6.—Carlot Arrivals in Boston of Apples and Chief Competing Fruits, 1921-1925

	1921	1922	1923	1924	1925	5-year Average
Apples	2,727	2,815	2,928	2,761	2,362	**2,719**
Bananas	6,880	6,737	5,915	6,609	7,850	**6,798**
Cantaloupes	1,401	1,702	1,452	1,558	1,699	**1,562**
Grapefruit	1,219	1,336	1,542	1,510	1,072	**1,336**
Oranges	4,055	3,294	4,650	4,427	3,387	**3,962**
Peaches	790	1,279	992	1,202	970	**1,047**
Pears	505	662	621	491	556	**567**
Berries	1,070	1,544	1,498	1,802	1,389	**1,461**
Other *a*	8,309	10,283	6,793	6,564	7,332	**7,856**
All Fruits	**26,956**	**29,652**	**26,391**	**26,924**	**26,617**	**27,308**

a. Chiefly grapes and cranberries.

Wholesale and Retail Distribution

It is evident that there must be a large distribution of apples from certain markets in the state, many small markets receiving their retail supply from these sources. Boston is naturally the greatest distributing point, supplying the entire demand, except what comes from local orchards, in the Eastern end of the state. The volume of these re-shipments is shown by the fact that the average annual carlot arrivals in Boston exceed the average annual unloads by about 1,000 cars. Wholesalers in other markets in this area, Lowell, Lawrence, Brockton, Taunton, buy through Boston practically all but those apples purchased directly from local growers. In New Bedford and Fall River wholesalers receive apples in carlots directly from New York and other sources and fewer through Boston.

Worcester wholesalers distribute to retailers in the city and in the small towns in the immediate vicinity. Fitchburg is a distributing center for a large area, which, however, consumes large quantities of home-grown apples. Springfield and Holyoke wholesalers do considerable business in nearby towns, while North Adams and Pittsfield dealers operate chiefly within their own markets.

Quantities Purchased by Retailers.

Formerly retailers bought large quantities of apples at a time, stored them in the best available space and took a chance on the keeping quality. Today most retailers buy from day to day, or at most two or three times a week. Many wholesalers, in discussing this matter, used the expression, "from hand to mouth" to show the small size of retailers' purchases. Some buy one box or two boxes at a time, while others buy from 5 to 10 boxes depending on the volume of business done. A few were reported as buying 25 bushels at once. An occasional retailer buys a considerable quantity of apples—usually barreled winter stock—keeping it in the wholesaler's storage space till needed.

When retailers buy from the growers they generally buy larger supplies than when they buy from the wholesaler. Most growers plan to sell their fruit before the weather grows too cold for hauling so that the retailers must generally depend on wholesalers for supplies after the holidays. This situation is particularly characteristic of markets in the western part of the state. Growers in this section sell considerable quantities directly to retailers and comparatively little to wholesalers. Some wholesalers reported that they do little or no business in apples until the new year, because of the competition of the growers' sales to retailers.

Retailers buy from growers, wholesalers and jobbers, and many of those in the vicinity of Boston who deal in Northwestern boxed apples, buy on the auction market in Charlestown.

Table 7 shows the proportion of retailers reporting who buy from grower and wholesaler in the different markets.

Over half (52 per cent) of the retailers reporting on this item buy more or less of their supply directly from growers; and 18 per cent buy from producers all the apples handled. Some retailers will not buy from the grower because he demands cash, whereas the wholesaler will usually extend credit.

While 82 per cent of the retailers reporting do business with wholesalers or jobbers, only 48 per cent buy all their apples from these firms.

TABLE 7.—Retailers Purchasing from Grower and Wholesaler

Market	Number Reporting	From Grower Only		From Jobber or Wholesaler Only		From Both Grower and Wholesaler	
		Number	*Per cent*	Number	*Per cent*	Number	*Per cent*
Boston	53	3	*5.7*	41	*77.3*	9	*17.0*
Brockton	22	5	*22.7*	15	*68.2*	2	*9.0*
Lowell	9	2	*22.2*	5	*55.5*	2	*22.0*
New Bedford	8	3	*37.5*	5	*62.5*	0	*0.0*
Springfield	32	10	*31.3*	19	*59.5*	3	*9.3*
Worcester	98	15	*15.3*	23	*23.5*	60	*61.2*
Miscellaneous	4	2	*50.0*	0	*0.0*	2	*50.0*
Total	**226**	**40**	*17.7*	**108**	*47.8*	**78**	*34.5*

In some of the markets of the western part of the state particularly, large quantities of apples are sold by the growers to the retailers. In Greenfield, for example, there is no wholesaler or jobber of apples, and there are few apples on the market except those from orchards in Franklin County. Formerly there were few apples of good quality, well graded, except those from the Northwest. The quality of home-grown apples has improved and the demand for them has increased accordingly.

Brands

Few Massachusetts apples are sold under a brand. A goodly number of growers, however, pack apples of such good quality that their names on box or barrel give sufficient assurance of satisfaction, both dealers and customers accepting the name as evidence of quality.

Most wholesalers who handle apples of specific brands reported that they buy, not according to the brand, but according to the condition and price of each lot purchased.

Container

Apples handled by retailers are commonly bought in barrels, boxes, bushel baskets and 14-quart baskets.

TABLE 8.—Percentage of Retailers Handling Apples in Each Type of Container

Market	Number of Reports	Barrels only	Boxes only	Baskets only	Barrels and Boxes	Barrels and Baskets	Boxes and Baskets
Boston	55	1.8	95.0	0.0	3.6	0.0	0.0
Brockton	21	85.7	9.5	0.0	4.4	0.0	0.0
Lowell	9	0.0	100.0	0.0	0.0	0.0	0.0
New Bedford	8	37.4	12.5	0.0	50.0	0.0	0.0
Springfield	31	70.0	9.7	3.2	12.9	0.0	3.2
Worcester	104	1.9	94.3	1.9	.9	.9	0.0
Miscellaneous	4	25.0	25.0	0.0	50.0	0.0	0.0
Total	**232**	**20.2**	**71.6**	**1.3**	**6.0**	**.4**	**.4**

A total of nearly 28 per cent of those reporting handle more or less barreled stock. Nearly four in every five retailers sell boxed apples, while but two per cent deal only in apples packed in baskets; these are dealers in Springfield and Worcester. In some markets, particularly in the southeastern part of the state, bushel baskets are common. The 14-quart baskets and smaller sizes, ranging to the 2-quart basket, are in general use at roadside stands.

Several enterprising growers of the state have in recent years packed considerable quantities of their best apples, usually McIntosh, in boxes holding a dozen. Some of these have been sold at roadside stands during the fall, some at retail stores, and some have been placed in cold storage and kept till late in the winter or early spring. These have been popular in those markets where offered.

It is evident that the preference for boxed apples is growing and that this preference is moving westward in the state. Boston, Lowell and Worcester already show an overwhelming demand for boxed fruit. New Bedford and Brockton still show a preference for barrels, but not so definitely as does Springfield.

Variety Preferences

Each of the 64 wholesalers reporting sells both fall and winter apples, but only 40 report the handling of summer varieties. Consumers report a decided preference for the McIntosh as an eating apple, 40 per cent liking this apple better than others. The Baldwin is second choice, more than 25 per cent naming this variety as their choice for eating. Other varieties, the Fameuse, Northern Spy, Roxbury Russet, Gravenstein come next in order, with 13 per cent dividing their choice among other scattered varieties.

The Baldwin is easily the favorite for cooking purposes, being named as their choice by nearly 60 per cent of consumers reporting. The Greening stands second, 19 per cent naming this variety. The McIntosh, it is rather surprising to discover, is third choice as a cooking variety, although it is reported by only 5 per cent of the consumers. The Gravenstein, also generally considered a table apple, is almost as popular for cooking purposes as is the McIntosh.

In New York City the Greening, according to a recent study[1], is in greatest demand for cooking, nearly one-fifth of over 3,000 consumers expressing a preference for this variety. The Baldwin, the favorite cooking apple in Massachusetts, is the choice of only 4 per cent of the reporting New York consumers. Nearly 35 per cent of these New York consumers have a definite preference for green apples for cooking, whereas Massachusetts housewives prefer red apples for both cooking and eating purposes.

The McIntosh is the favorite eating apple in New York City as in Massachusetts, and this demand is largely among Jewish consumers. Indeed, in the New York market, it is sometimes called "the Jewish apple." The demand for Baldwin is about the same as that for Delicious, some 8 per cent of the consumers reporting expressing a preference for these varieties. The Fameuse apple is best liked by about 7 per cent of the consumers; but no other variety even approaches these in popularity.

Some growers and dealers have felt concern lest the large plantings of McIntosh trees may mean over-production within a few years, but there seems little fear of this because of the growing popularity of the variety in practically all markets. New York prefers the McIntosh apple from New England because it takes on a better color and has a better flavor than those from New York orchards. The New York market has also taken kindly to the Massachusetts boxed McIntosh in the last two years although it has been considered as distinctly a barrel market. The wrapped New England apple has also recently met with favor in New York City, indicating that the demand in that market for our best apples is increasing.

Dealers report that the demand for eating apples is increasing while that for cooking apples is steadily decreasing. Formerly housewives did much more baking of pies and puddings than they do at the present time, and used many more apples for these purposes. Today many housewives bake no pastry. Of those reporting for this study about one in eight uses no apples for making pies. Bakeries, on the other hand, bake pies for consumptoin in the home and in public eating places.

The housewife of today serves more salads than did her mother and her grandmother, and for this purposes eating apples are preferred to the strictly cooking varieties.

Consumer Buying—Quantity Purchased

About one-third of the consumers reporting for this study buy a bushel of apples at a time, and 12 per cent buy by the barrel. These are mostly in the western part of the state and report also adequate storage space.

Of those who buy by the bushel, about 85 per cent buy from the grower or at the roadside stands; and 7 per cent buy from the grocer. Others buy from various sources as happens to be convenient.

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[1] Unpublished data from this study were supplied by Mr. E. R. French of the New York Food Marketing Research Council.

Seven in ten of those who buy a barrel at a time deal directly with the grower and nine in ten buy either from the grower or from the roadside market. Eight per cent buying barreled apples secure them from their grocers, while others report buying from several sources.

Over thirty per cent of reported consumers' purchases were by the peck or by the 14-quart basket, the latter chiefly in Springfield and vicinity, although there are some baskets sold in Worcester.

Sales by the Pound

There has been in the last few years a marked increase in the buying of apples by the pound, and a corresponding decrease in purchases by the peck, bushel or barrel. From the retailer's standpoint practically all sales are by weight. Sales "by the piece" are the only exceptions. A peck of apples must weigh 12 pounds in Massachusetts and the retailer weighs out 12 pounds when the customer orders a peck of apples, or 6 pounds when a half-peck is ordered. Often the customer orders "25¢ worth" of apples, and the retailer adjusts the apples to this amount by weight— 3 pounds, 4 pounds, or 5 pounds "for a quarter."

Retailers reported that the customer seems to prefer to purchase 25 cents worth even though a better bargain be offered at slightly different amounts. For instance, more apples will be sold if 5 pounds are given for 25 cents than if 6 pounds are offered for 28 cents. It is reported by retailers that a real bargain at more than 25 cents or less than 25 cents will cause a falling off in volume of sales, whereas a reduction of the number of pounds offered for 25 cents will not materially affect the number of sales.

Sales "by the piece," varying from one apple to a dozen, comprise 3 per cent of all retailers' sales reported. These are largely at fruit stands, and the price is commonly 5 cents each, although sometimes apples are sold at 3 for 10 cents, or even 10 cents each.

The custom of buying in small quantities has developed because (1) the storage facilities of the average home, particularly city homes, are small, and there is not room enough for large quantities of supplies; (2) the cash and carry system has induced the purchase of small lots by the consumer; (3) apples which have been in cold storage do not keep well when removed from storage, and the consumer therefore finds it wiser to buy small lots of these apples.

Factors in Buying

One-fourth of the consumers say that they are guided in their selection by the condition of the fruit. Size is considered, according to these reports, by but 14 per cent, but it is well-known among retail and wholesale dealers that there is a decided preference for apples of medium size. Color, likewise, is named as of importance by but 7 per cent of the consumers, although it is a matter of general information that red apples are the only ones commonly desired for household use.

The flavor of the apple is taken into consideration by 16 per cent of those reporting, and juiciness, texture of the flesh, and cooking quality are mentioned by a few.

Seven per cent of the consumers report that they buy by variety; and an equal number say they buy apples because of their healthfulness.

The grade and pack and brand are reported by a very few consumers as items of consideration.

Consumer and Known Varieties

Of the 488 consumers reporting, 35 (7 per cent) report no varieties of apples which they can identify and 20 name only one variety. The Baldwin is known to 94 per cent of the consumers reporting, while 77 per cent know the McIntosh and not quite half know the Russet, the third best known variety. Not one in three knows the Greening; only one in five knows the Gravenstein, and about one in six knows the Northern Spy.

Grades Preferred

In order to determine as accurately as possible the grades and sizes desired by different kinds of retail trade, stores (chain and individual), hotels and restaurants, fruit stands and hucksters or peddlers were classified into cheap, medium and exclusive. The following tabulation presents this information as secured by inquiry from wholesalers.

It is noteworthy that the Fancy grade is in demand only among the high-grade stores. "A" grade apples are most in demand, 58 per cent of all types of retail agencies handling them, and 44 per cent of the retail stores report that they handle this grade alone. Over 60 per cent of the reported demand of chain stores, fruit stands, hotels and restaurants is for "A" grade, and 52 per cent of the demand from individual stores is for this grade. Only 12 per cent of the total demand, as reported by wholesalers, is for "B" grade fruit. Ungraded lots, with a demand amounting to 20 per cent, are more popular than "B" grade.

TABLE 9.—Grades and Sizes Preferred by Different Types of Retail Trade.[a]

Type of Trade	Number of Times Named				Sizes (Inches)
	Fancy	A	B	Ungraded	
CHAIN STORE					
Cheap	0	5	7	9	2 —2½
Medium	0	24	7	3	2¼—2¾
Exclusive	0	15	0	0	2½—3+
INDIVIDUAL STORE					
Cheap	0	27	15	30	2 —2½
Medium	0	14	1	1	2¼—2¾
Exclusive	5	16	0	1	2½—3+
HOTELS AND RESTAURANTS					
Cheap	0	16	3	12	2½
Medium	0	21	4	8	2½—2¾
Exclusive	8	21	0	3	2½—3+
FRUIT STANDS					
Cheap	0	0	2	1	2 —2½
Medium	0	21	4	2	2½—3
Exclusive	17	22	0	0	2¾—3+
Total	**30**	**202**	**43**	**70**	

[a] The Massachusetts grades are considered throughout this bulletin.

Reports of cash-and-carry stores show that 66 per cent use A grade apples, and 27 per cent A grade only. The demand for Fancy apples is confined to 7 per cent of these stores; 14 per cent want B grade, and 6 per cent want this grade only. The remainder handle any grade or unclassified. Three per cent report a demand for unclassified only.

The nine self-service stores reporting show that five handle A grade apples only; one handles both A and B and the other three handle unclassified apples.

Hucksters buy mostly according to price, with variety, grade and size of minor importance.

An analysis of the demand as influenced by the nationality of consumers shows that 63 per cent of stores patronized wholly or mostly by people of native stock want A grade only; while 70 per cent of those with a patronage largely Swedish, and 55 per cent of those catering largely to French, use A grade only. The sale of B grade only is reported by 32 per cent of the stores having mainly American custom and 20 per cent of those chiefly or partly Irish.

Sizes Preferred

Preferences are very definitely for one size in a container, nearly three-fourths of those retailers reporting state this choice; 8 per cent prefer assorted sizes in a container; while 18 per cent express no preference. Preference for assorted sizes within a container applies mostly to cheaper varieties and grades of apples, often to those to be used for cooking.

The preference is in general for apples about 2½ to 2¾ inches in diameter. This is the first choice of practically every buyer, but with the cheapest trade, price controls the purchase as to grade, size and variety. Table 9 presents the favored sizes reported by different types of trade.

As in the case of grades, so the size of apples purchased by hucksters is a consideration secondary to price, as they depend chiefly on a glutted market for their supply, and buy whatever they think they can sell at a profit.

Practically all wholesalers reported that fruitstand operators wish only good grades and the larger sizes of apples. As this fact indicates, there are few cheap fruit stands and these where there is little trading by hucksters.

Uses of Apples

From information furnished by consumers, it is evident that the following statement of proportion of apples used for different household purposes is fairly typical, although it must be understood that there are many and wide variations therefrom.

Uses	Per Cent	Uses	Per Cent
Raw	50	Baking	10
Pies	20	Salad	5
Sauce	10	Other	5

Advertising

Little effort seems to be made by most retailers to push the sale of apples. In general they apparently prefer to make a larger margin of profit on a small volume of sales rather than put forth the effort necessary to handling a large volume.

The common method of advertising apples which is used in retail stores is the mere display of the fruit in the original container. Seventy-two per cent of the retailers interviewed display apples in boxes, 31 per cent display a bushel at a time; 30 per cent display them in the window and now and then one reports that he displays them in a showcase. Some use bins for display purposes, these being sometimes built in the window. Occasionally the placard advertising the price states also the variety, and less often the grower's name is given.

Six per cent of the retailers reporting advertise the brands of apples they handle. Eleven per cent advertise apples in local newspapers, and 8 per cent advertise them more or less by some sort of circular.

During national apple week, early in October, considerable effort has been made to advertise Massachusetts and New England apples. The campaign has been carried on under the leadership of the State Department of Agriculture, Division of Markets, which has enlisted the cooperation of chambers of commerce in the markets of the state. Not only the retail markets, but dry goods, hardware, and other types of stores, have entered into the movement. Window displays entirely or partly composed of apples have been used.

One wholesaler in particular has, for a number of years, advertised apples throughout the western part of the state, using the side of his big business block as well as bill-boards at several points on state highways.

The Nashoba Apple Growers' Association, with over 300 members in the apple district in Middlesex and Worcester counties, and also in southern New Hampshire, advertises apples by means of billboards marking the area of what is known as the Nashoba apple district.

Roadside stands advertise apples by means of signs at or near the stands. Usually these signs announce the varieties chiefly sold, particularly McIntosh; and the name of the grower is sometimes added.

THE FOREIGN MARKET

The World Crop

The volume of the world crop in apples can not be exactly stated, since returns are not available from all countries, Russia, Belgium and some others not being reported. However, statistics compiled by the United States Department of Agriculture include the bulk of the world's apple crop. These are included in the following table. It will be noted that figures for Canada and New Zealand represent commercial crops only.

TABLE 10.—Apple Production in the Chief Producing Countries, 1921-1924 (barrels)

Country	1921	1922	1923	1924
NORTHERN HEMISPHERE *a*				
United States				
Total Crop	33,000,667	67,567,333	67,614,000	59,700,333
Commercial	21,557,000	31,945,000	35,936,000	28,587,000
Canada, Commercial	4,165,527	3,889,541	3,838,641	2,965,492
England and Wales	. . . .	. . . .	3,609,000	2,738,000
France *b*	2,607,154	5,391,670	3,416,165	5,772,929
Czechoslovakia	2,554,202	4,929,986	2,838,934	3,664,354
Yugoslavia	2,335,853	2,681,386	2,098,305	2,767,528
Bulgaria	2,560	2,851	. . . .	. . . .
Italy	2,742,000	. . . .	. . . .	. . . .
Switzerland	1,113,161	3,696,995	550,667	1,690,333
Chosen	147,628	149,520	182,090	225,252
Japan	416,637	992,023	459,362	. . . .
SOUTHERN HEMISPHERE *a*				
Chile	55,708	133,366	. . . .	. . . .
Australia	2,182,045	2,399,783	1,947,426	. . . .
New Zealand, commercial	329,871	489,748	465,633	521,086
Total of countries reporting	**51,653,013**	**92,324,202**	**87,020,223**	**80,045,307**

a. Production as reported is for the calendar year in the Northern Hemisphere and the succeeding harvest in the Southern Hemisphere.

b. Pears and apples for table use included.

The United States grows about 73 per cent of the world crop reported and our commercial crop amounts to about 30 per cent of this known volume. Canada is the next largest producer, with a commercial crop averaging 3,750,000 barrels for the period under discussion. Czechoslovakia produced an average of 3,500,000 barrels during the period, the largest volume for any European country reporting. France grows a crop of considerable size, but the figures given in this table include not only those apples for table use, but pears as well.

Although apples are grown more generally than any other fruit, being cultivated to some extent in most parts of the world, many countries do not produce enough to meet their own demand and a world-wide apple trade has developed. A partial summary of this international trade is presented in the following tables, 11 and 12, which list the chief countries importing and exporting apples. The figures, which were compiled by the agents of the United States Department of Agriculture, show that most of the exporting countries also import apples to some extent.

The total volume of imports reported exceeds the total volume of exports, indicating that there are sources of considerable exports other than those listed.

International Trade

International trade in apples, which amounted to about 7,000,000 barrels annually from 1909 to 1913, has not yet quite reached this pre-war level. Of the average for the 5 years, 1921-1925, the United States contributed 42 per cent and Canada 23 per cent, Australasia about 9 per cent and France 7 per cent. The remainder is exported by various continental countries. Table 11 gives export statistics of the principal countries from 1921 to 1925.

Table 11—Total Apple Exports, by Chief Countries, 1921-1925 (barrels)*a*

Country	1921	1922	1923	1924	1925
United States	1,936,000	1,648,000	2,959,000	4,120,000	3,347,000
Canada *b*	1,358,000	1,846,000	1,461,000	1,653,000	1,388,000
Australia *c*	291,000	582,000	662,000	455,000	704,000
France *d*	150,000	57,000	252,000	1,515,000	422,000
Netherlands	307,000	116,000	251,000	353,000	. . .
Italy *d*	23,000	28,000	404,000	544,000	468,000
Austria *d*	15,000	7,000	10,000	931,000	118,000
Belgium	105,000	187,000	263,000	328,000	. . .
Switzerland	50,000	24,000	16,000	560,000	96,000
Yugoslavia	65,000	35,000	11,000	172,000	82,000
Portugal *d*	55,000	25,000	29,000	55,000	. . .
New Zealand	14,000	31,000	41,000	68,000	59,000
Czechoslovakia *d*	3,000	3,000	5,000	5,000	97,000
Hungary *d*	. . .	300	. . .	. . .	167,000
Rumania *d*	. . .	1,000	. . .	. . .	159,000
Total	**4,372,000**	**4,590,300**	**6,364,000**	**10,759,000**	**7,107,000**

a. From Commerce Reports, July 26, 1926.
b. Canadian fiscal year begins April 1.
c. Australian fiscal year begins July 1.
d. Apple export statistics include also pears or quinces. These figures are reported by chief apple importing countries.

Table 12.—Total Imports of Apples, by Chief Countries, 1921-1925, (barrels)

Country	1921	1922	1923	1924	1925
United Kingdom	3,108,000	3,473,000	5,028,000	5,617,000	4,667,000
Germany	. . .	28,000	506,000	3,772,000	2,865,000
Canada	273,000	111,000	196,000	172,000	124,000
Sweden	91,000	68,000	154,000	216,000	. . .
Denmark	102,000	85,000	137,000	139,000	. . .
Norway	80,000	53,000	98,000	58,000	47,000
Netherlands	64,000	58,000	107,000	121,000	. . .
Belgium	127,000	30,000	41,000	104,000	. . .
Mexico	42,000	33,000	39,000	47,000	30,000
Cuba	34,000	34,000	44,000	41,000	38,000
Argentina	10,000	28,000	59,000	87,000	143,000
Brazil	14,000	14,000	19,000	37,000	59,000
Philippines	11,000	26,000	37,000	53,000	41,000
China	7,000	9,000	15,000	24,000	24,000
Total	**3,963,000**	**4,050,000**	**6,480,000**	**10,488,000**	**8,038,000**

The volume of apples exported from the United States varies obviously with the size of the crop. Domestic markets are, in general, supplied first, and the surplus sent to foreign markets. When the crop is small the home markets absorb larger proportions, leaving less for export. The total volume of exports from the United States has ranged from 497,000 barrels in 1901-02 to 3,511,000 barrels in 1923-24, with an average of over 1,700,000 barrels for the entire period. The table following gives the exports from the United States for these seasons, 1901-02 to 1925-26.

TABLE 13.—Volume of Apples Exported from the United States, 1901-02 to 1925-26

Season	Barrels	Season	Barrels	Season	Barrels
1901—02	497,000	1909—10	1,096,000	1917—18	635,000
1902—03	1,981,000	1910—11	1,619,000	1918—19	1,577,000
1903—04	2,308,000	1911—12	1,449,000	1919—20	997,000
1904—05	1,683,000	1912—13	2,299,000	1920—21	2,114,000
1905—06	1,437,000	1913—14	1,285,000	1921—22	826,000
1906—07	1,649,000	1914—15	2,148,000	1922—23	1,393,000
1907—08	1,436,000	1915—16	1,466,000	1923—24	3,511,000
1908—09	832,000	1916—17	1,740,000	1924—25	3,201,000
				1925—26	3,189,000

Exports have comprised, since the World War, an average of nearly 7 per cent of the commercial crop of the United States. The table below presents the total commercial production of apples, with the percentage exported from each season's crop, from 1918-19 to 1925-26.

TABLE 14.—Commercial Production of Apples in the United States, with Percentage Exported, 1918-19 to 1925-26

Season	Bushels	*Percentage Exported*
1918-19	74,229,000	*6.3*
1919-20	78,477,000	*3.8*
1920-21	101,715,000	*6.2*
1921-22	64,671,000	*3.7*
1922-23	95,835,000	*4.3*
1923-24	107,808,000	*9.8*
1924-25	86,103,000	*11.1*
1925-26	95,927,000	*9.9*

European countries offer the chief markets for apples exported from the United States, the United Kingdom and Germany taking more than all other countries.

United Kingdom

The apple markets of Great Britain are supplied in large part during the fall and early winter by the European crop. During this season the British markets consume first the home-grown supply, hence the crop in England is especially significant to the United States exporter, since British markets absorb so large a portion of our exports.

The home-grown apple crop normally supplies from 8,000,000 to 9,000,000 bushels for the British market. These are mostly cooking apples. The small supply of native dessert apples is commonly exhausted by the beginning of the new year.

Canada is the chief competitor of the United States in the markets of the United Kingdom, to which she sent during the seasons from 1921 to 1925 an average of 95 per cent of all apples exported. The following table presents the total exports of apples from Canada from 1900 to 1925.

Table 15.—Canadian Exports of Apples, 1900-01 to 1925-26a (barrels)

Season	Exports	Season	Exports	Season	Exports
1900—01	470,000	1909—10	1,605,000	1918—19	405,000
1901—02	394,000	1910—11	527,000	1919—20	874,000
1902—03	633,000	1911—12	1,664,000	1920—21	1,358,000
1903—04	1,327,000	1912—13	1,325,000	1921—22	1,285,000
1904—05	1,043,000	1913—14	947,000	1922—23	1,370,000
1905—06	1,218,000	1914—15	1,117,000	1923—24	1,510,000
1906—07	978,000	1915—16	577,000	1924—25	1,371,000
1907—08	1,629,000	1916—17	571,000	1925—26	1,393,000
1908—09	1,092,000	1917—18	104,000		

a. Compiled from The Canada Yearbook and the reports of the International Apple Shippers Association.

Statistics of production in France are incomplete, but in 1924, the most recent year for which figures are available, a total volume of 5,772,929 barrels was grown. This figure, however, includes pears and peaches as well as apples, but a careful estimate from the United States Department of Commerce places the probable total production of apples in France as considerably above this figure. During the decade 1903-1913 the average exports from France to the United Kingdom amounted to 222,000 bushels, and for the period from 1920 to 1924 this average was 617,000 bushels, about 5 per cent of the total importations of the United Kingdom. Germany received an annual average of 3,916,000 bushels of apples from France during the decade preceding the war. In 1925 the volume had regained but 24 per cent of this pre-war average.

Apples exported from Australia and New Zealand are sent almost wholly to the United Kingdom. The normal crop is between 2,000,000 bushels and 3,000,00 bushels, of which Tasmania grows more than half and New Zealand some 10 per cent. The bulk of the shipments occur in May and June, and most of these apples are shipped to London.

Obviously only the last of the United States apples held in storage meet the competition of the Australasian crop, and the quality of these apples is not equal to those grown in the United States. The cost of packing and carriage to the London market is reported to be $2.00 a case (bushel), which gives a decided advantage to apples shipped from our North Atlantic ports.

During the season 1925-26 Russia resumed shipping apples to England, having suspended these exports since the beginning of the World War. In quality the Russian apple is not at present a serious competitor of American fruit. The Russian crop is, however, said to attain a color that shows the possibility of competition should the Russian grower learn better cultural methods.

Germany

Germany was, prior to the World War, a large importer of apples, but only during the past two or three seasons is she receiving again large shipments from the United States. Importations of apples by the United Kingdom and by Germany are presented in Table 16. Owing to geographical changes following the World War, the figures for German importations are not exactly comparable to the pre-war figures. British importations of apples from the United States have more than doubled the pre-war average, while the volume sent to Germany has not yet returned to that of the decade prior to the war.

TABLE 16.—British and German Imports of Apples (barrels)

United Kingdom			Germany		
Source	Average 1909—1913	Average 1921—1924	Source	Average 1903—1913	1925 *a*
United States	958,000	1,904,000	Netherlands	297,000	679,000
Canada	1,094,000	1,324,000	Italy	682,000	468,000
Australia	276,000	563,000	France	1,305,000	422,000
France	74,000	206,000	Belgium	287,000	317,000
Belgium	75,000	111,000	Hungary	. . .	167,000
Netherlands	21,000	78,000	Rumania	. . .	159,000
Portugal	91,000	41,000	United States	143,000	131,000
New Zealand	. . .	41,000	Austria	. . .	118,000
Germany	3,000	12,000	Czechoslovakia	. . .	97,000
Channel Islands	10,000	2,000	Switzerland	370,000	96,000
Other	14,000	25,000	Yugoslavia	. . .	78,000
Total	**2,616,000**	**4,307,000**	Austria-Hungary	723,000	. . .
			Canada	37,000	. . .
			Australia	33,000	. . .
			Russia	11,000	. . .
			Other	8,000	134,000
			Total	**3,896,000**	**2,866,000**

a. Germany imported very few apples from 1920-1924.

France

The demand for American apples in France has been very small. French markets demand better grades of apples than do British markets. Since most receipts of American apples in France have been reshipments from London or Liverpool, the French have not found them equal in size or quality to their own table apples, hence they have not been popular.

During the season of 1925-26, however, after French apples had become scarce and expensive, Northwestern boxed apples of good size were offered on the Paris markets after careful advertising. Certain chain stores handled them at a reasonable price. This tended to control to some extent the retail price in other stores and the price asked for good American fruit was lower than that of the remaining French apples which were withered and over-ripe. This served to extend the consumption and introduce American apples to the French public.

South America

While comparatively few apples are shipped from the United States to South American countries, the shipments averaging only about 3 per cent of total exports since the war, the average volume of apples exported to South America is nearly 125,000 bushels. Most of these are sent to Brazil, where native fruits are the chief competitors of United States apples, although some apples are received from Canada, New Zealand and Portugal.

The demand for American apples comes chiefly from the most prosperous classes, largely foreigners. The few available reports show that prices are high. It seems probable that better shipping facilities, with proper refrigerator service and efficient advertising might open a wider market in South America.

Canada

Despite the fact that Canada is herself a large producer of apples, she ranks third as an export market for United States apples. She takes about 9 per cent of our boxed exports and 2 per cent of our barreled apples. Canada also ships some apples into the markets of the United States, although the bulk of her exports is shipped to the United Kingdom.

Sources of Exports

The chief sources of apples exported from the United States are New England—especially Maine and Massachusetts—New York, Virginia, and the Pacific Northwest, but it is impossible to determine how many are exported from any producing section, since records of sources are not always available. Customs House records may or may not give actual place of origin, as the shipper may buy apples in the Northwest and ship them from Boston or New York. Apples grown in Maine are often shipped from New York, and Northwestern apples have been stored in Portland, Maine, and exported from that port.

Several of the largest exporters in Boston reported for the season of 1924-25 total exports of about 55,000 bushels of Massachusetts apples. Of these almost all were boxed apples; only 3,327 bushels were shipped in barrels. These figures probably represent a large part of Massachusetts apples exported by Boston dealers, although there are a few wholesalers who now and then export apples as conditions seem favorable, but whose figures are not available. There is apparently no regular exporter in Massachusetts outside of Boston.

Varieties Exported

A more or less accurate idea of the relative volumes of different varieties exported from New England can be formed from figures provided by a few individual exporters of Boston. From exports amounting to 18,800 bushels shipped, mostly from Boston, in 1925-26, the following percentages of varieties are given:

Variety	*Per Cent*	Variety	*Per Cent*
Gravenstein	*22.7*	Baldwin	*17.7*
Early Williams	*7.4*	Ramshorn	*2.07*
Wealthy	*10.5*	Ben Davis	*2.3*
McIntosh	*22.4*	Odd Varieties	*4.9*
		Not reported	*10.1*

Since these reports were for the season of 1925-26, in which the foreign trade in winter apples was injured by the appearance on some shipments of arsenic spray residue, it is probable that there is a larger proportion of fall apples than would appear in most reasons.

Boxed and Barreled Exports

In the season of 1925-26 about 40 per cent of all apples exported were boxed. Shipments from Eastern ports were 70 per cent barreled and only boxed apples were shipped from the Western ports.

The proportions of boxed and barreled apples consumed by different countries is of interest to the export trade. During the three seasons from 1922 to 1924, England, Ireland, Sweden, Denmark, Norway, Brazil and Argentina increased the proportion of barreled apples from the United States. Canada, Germany, Netherlands, Mexico, and Cuba show declining receipts of barreled apples, with corresponding increases in boxed apples. Germany, despite her irregular imports since the war, shows an increasing demand for boxed apples. China and The Philippines take few if any apples in barrels.

The total percentage of boxed apples exported has increased almost steadily since the season of 1900-1901. During the first five years of the period, the average was about 5 per cent of the total exports from the United States. The five years immediately preceding the war showed that this had risen to 25 per cent, and since the war it has reached an average of 54 per cent.

Tariffs

Great Britain imposes no tariff on imported apples, but continental governments impose tariffs varying from 6 cents, the minimum per 100 pounds, for apples in bulk, to $11.00 per hundred-weight for "fresh fruits in fancy packing" in Belgium. On apples for table use, France imposes an import duty varying from 21 cents to 85 cents per 100 pounds, while apples for cider are taxed from 9 cents to 34 cents.

Germany has a new tariff which varies according to the season, imposing on unpacked apples a lower rate during the last three months of the year. This has the effect of restricting the trade in American apples during that period, because of the obvious impossibility of successful ocean shipment of unpacked apples. The German tariff on American apples is 33 cents a box and $1.09 a barrel. This places barreled fruit at a disadvantage if exported to Germany, but the German market shows a growing preference for boxed apples, most of the best native fruit being now so packed. The tariff on Canadian apples shipped to Germany is $1.59 per 100 pounds, Canada not being included in the "favored nation" clause of German treaties. Hence Canada exports few apples to Germany.

Norway imposes on American apples a duty which is nearly 100 per cent higher during the last five months of the calendar year than during the other seven. It is claimed that this is for the protection of the Norwegian apple growers. This tariff has had the effect of limiting importation of apples during the latter part of the year, since it amounts to nearly 5 cents a pound, while from January first to July 31st it is about 2.7 cents a pound. The commercial treaty between Spain and Norway gives oranges a great advantage in Norwegian markets over imported apples, the duty imposed on oranges amounting to but $.0012 per pound, with no seasonal variation. Unless this situation is changed there will be little opportunity for imported apples in Norway.

Transportation

Several matters of transportation are of importance in connection with the exporting of apples. Especially should growers who ship directly to foreign markets be familiar with the routine as to refrigeration, insurance and costs of handling.

Refrigeration

Refrigerated space varies with the different boats, some having only ordinary stowage and others having two, three or five refrigerated chambers. These compartments vary in size according to the space between decks. It is possible to cool one chamber alone and to maintain a different temperature in each chamber. The temperature can be maintained within two degrees of any point specified. Temperatures are therefore stated as "34-36," "32-34," etc. Probably 35 degrees is most desirable for apples.

Since few perishables are brought from European ports to United States ports, boats westward bound seldom use refrigerated space. Boats incoming are frequently notified by wireless that certain refrigerated space of a specified temperature will be needed for the return trip. This advance notice gives time to get the chamber ready for prompt loading on arrival at port.

There are no boats in the Atlantic service containing only refrigerated space; but in the Pacific Coast trade ships wholly under refrigeration are used to carry part of the apple shipments from the Northwest by way of the Panama Canal. Obviously one of these ships will carry large quantities and some concern has been felt as to the effect on foreign markets of these large shipments.

Insurance

Insurance of apples for export covers ordinary marine risks, the owner being protected against actual damage or loss, not to exceed the declared value. The cost of this insurance is ordinarily about one per cent of the value. There are, in addition, special insurance features for the protection of shippers of perishable fruits against loss due to prolongation of the voyage. Such delays arise most often from broken machinery.

Apples shipped under refrigeration are also commonly insured against breakdown of refrigeration machinery. At a slightly higher cost the policy can be written to cover loss from insufficient refrigeration, which is one of the chief sources of loss to exporters, who are now endeavoring to secure more satisfactory arrangements with regard to the maintenance of proper temperatures. The International Apple Shippers Association and individual exporters are concerning themselves with this matter.

Under ordinary circumstances the condition of apples on arrival at foreign ports is determined by the condition when shipped and the character of the pack. Apples of good quality properly packed usually arrive at the end of the voyage in good condition. Assuming that the variety, condition and pack are suitable for export, no loss which is not insurable need be expected.

Costs of Exporting

Export charges are comprised of freight, refrigeration, insurance, commission and a group of costs known as "consolidated charges" in British ports. These last are made up of quay or wharf charges, porterage, cartage, selling costs, etc. The freight from any North Atlantic port to any British port, as fixed by the North Atlantic Conference of representatives of steamship lines trading with ports of the United Kingdom, is 90 cents a barrel, if shipped in common stowage, or $1.40 a barrel if shipped under refrigeration. Boxes are shipped in common stowage for 30 cents each, or for 50 cents if refrigerated space is required. Rates on baskets and fibre containers are comparatively higher, being 25 cents per cubic foot carried in common stowage, and 35 cents if in refrigerated space. These higher rates are imposed because the steamship companies distrust this type of container.

The "consolidated charges" are the most variable costs named, changing with the changes in labor costs and varying from port to port. During the two seasons of 1924-25 and 1925-26, these charges were as follows in the chief ports receiving American apples:

Port	Barrel	Box
Manchester	$.363	$.22
Liverpool	.343	.22
Hull	.323	.20
Glasgow	.363	.20
London (Surrey commercial docks)	.486	.243
London (Tilbury, King George V, and other docks)	.606	.243

Typical sets of exports charges on barreled and boxed apples, shipped from New York to Liverpool, which received in 1925-26 one-third of the apples exported from the United States, are given below:

TABLE 17.—Typical Export Charges, New York to Liverpool

	Barreled		Boxed	
	Refrigerated	Common Stowage	Refrigerated	Common Stowage
Freight	$1.40	$ .90	$ .50	$ .30
Insurance *a*	.05	.05	.02	.02
Commission	.35	.35	.14	.14
Consolidated Charges	.343	.343	.245	.245
Total	$2.143	$1.643	$ .905	$ .705

a. Insurance and commission based on assumed valuation of $5.00 per barrel and $2.00 per box.

These charges are deducted from the price received and the balance remitted to the American shipper. Under ordinary conditions the shipper may expect returns in about two weeks. Some firms report within a few days the price at which apples have been sold.

Charges on apples exported to Germany are stated as follows in a report from a Federal agent stationed in that country: Broker's charge 6 per cent which includes commission, discounts to buyers, credit risks and cataloguing for the auction markets. There are additional charges which include inspection fees, pier expenses and four weeks of free storage to buyers. Shippers from New York must calculate for all commissions and costs, including ocean freight, about 85 cents a box and $2.06 per barrel for common stowage, and about $1.05 a box and $2.43 a barrel, if refrigerated space is required. Total expenses on shipments from the West are about $1.38 a box, shipped in cold storage. Insurance amounts to about 4 cents additional. Obviously, costs of exporting to Germany are considerably higher than on shipments to the markets of the United Kingdom.

Packing for Export

The problem of packing apples for export differs from packing for domestic markets. Owing to the long ocean haul which tends to cause shifting of the fruit within the container, the apples should be packed very tightly or the package reaches the other side in what is known as a "slack" condition. This is more common with barreled than with boxed apples. The apples in a "slack barrel" have settled so that they do not come in contact with the head of the barrel and have received more or less injury from shifting.

Barrels are tested for slackness and are classified in some markets on this basis, when offered at auction. The Liverpool auction classifies barreled apples as "tight," "slack," "slightly wet," and "wet." Other markets require buyers to judge for themselves as to the condition of the fruit. Naturally, slack barrels bring lower prices than fruit that is properly packed. The common discount on slack barrels is from one to two shillings, although it sometimes amounts to three or even five shillings.

Buyers naturally hesitate to ship slack barrels long distances, and these apples must therefore be marketed near the port. This restricts distribution and tends to keep prices down in the large receiving markets. It is, therefore, greatly to the advantage of the grower who wishes to export his apples to pack them securely and avoid slack packages.

The causes of slack barrels are chiefly poor barrels, poor packing, rough handling, and poor or over-ripe fruit. Fewer slacks appear in refrigerated fruit than in that which is shipped in ordinary stowage.

The use of shredded paper is not advised by shippers, as the paper can not be packed tightly enough to prevent shifting of the fruit, especially if the paper becomes wet. It is better to put in more apples, shake them carefully down, and press well.

In general it seems to be true that there is greater waste and consequently greater loss on barreled fruit. There is commonly less care in packing barrels than when apples are packed in boxes; there is more dishonesty in the packing of barreled apples, and dishonesty is expensive.

For the British market packages should not be faced, according to the advice of the foreign agents of the United States Department of Agriculture. Many British dealers feel that all facing is dishonest and pay lower prices for packages so packed, even though the entire contents of the package are exactly the same as the apples on top.

Spray Residue

Growers who offer apples for export need to give special attention to spray residue. English law forbids the sale of apples which show more than 1/100 of a grain of arsenic per pound of apples. Fruit showing more than this amount of arsenic is liable to exclusion from all English ports or to seizure if landed. Apples which show spray residue should be carefully wiped before packing for any market, foreign or domestic.

Brands

Growers or dealers who export apples under a brand find it desirable to register that brand with government officials in certain countries. In Brazil and Argentina, in particular, this registration protects the exporter, giving him the sole right to distribute his product. Failure to register may deprive him of this right, since any person, not necessarily the owner, may register an unregistered brand.

The costs of this registration vary. In Great Britain it costs about $30.00; in Argentina from $65.00 to $85.00, and in Brazil from $75.00 to $90.00

Instructions with regard to the methods of registering a brand may be secured by addressing the United States Department of Commerce, Washington, D. C.

Storage

If apples are placed in cold storage in England, the costs are increased by 10 cents to 13 cents a box, and 40 to 60 cents a barrel, for the first month and about 14 cents each week thereafter. Handling charges into storage vary in the different ports, but amount in Liverpool to 8 cents a barrel and 2.2 cents a box, and in London to about 20 cents a barrel and 6 cents a box.

TABLE 18—Preferences in Foreign Markets.

Market	Container	Color	Size	Varieties	Time of Demand for United States Apples
GERMAN AND DUTCH Berlin	1. Box 2. Barrel	1. Red		Jonathan Spitzenburg Winesap York Imperial Newton	After January 1st
Bremen	1. Box	1. Red 2. Yellow	138 (few) 150-200	Jonathan Spitzenburg Newtown Winesap	December 15 (red only) After January 1st
Hamburg	1. Box	1. Red	125 (few) 150-200	Jonathan Spitzenburg Winesap Newtown	November
Rotterdam	1. Box	1. Red 2. Yellow	150-200	Jonathan Spitzenburg Winesap Newtown Rome Beauty	After January 1st
BRITISH Bristol	1. Barrel 2. Box	1. Red	175-200	York Imperial	After January 1st
Glasgow	1. Box	1. Red 2. Yellow		Delicious Newtown Jonathan York Imperial Spitzenburg Baldwin Ben Davis	
Hull	1. Box 2. Barrel	1. Red 2. Yellow	163-175		January-April
Liverpool	1. Box 2. Barrel	1. Red			
London	1. Box 2. Barrel	1. Yellow 2. Red	175, 188, 200, 216	Cox Orange Pippin Newtown Jonathan York Imperial Spitzenburg Arkansas Black Winesap	February 1—May 1

Manchester	1. Barrel	1. Green	150	Newtown York Imperial	
Newcastle-on-Tyne	1. Box 2. Barrel	1. Red 2. Yellow		York Imperial Newtown	
Southampton		1. Red 2. Yellow 3. Green	163-234	Baldwin Ben Davis Rhode Island Greening Jonathan Rome Beauty	January—April
Cardiff	1. Barrel	1. Red	175-200	York Imperial Baldwin Stark Newtown	September—February
Swansea	1. Barrel 2. Box			Baldwin Ben Davis Jonathan King Gravenstein Newtown Winesap York Imperial	September—March
SCANDINAVIAN Copenhagen	1. Barrel 2. Box	1. Red	138-200	York Imperial Jonathan Spitzenburg Winesap Newtown	December—May
Gothenberg	1. Barrel 2. Box				January 1st
Oslo	1. Barrel 2. Box	1. Red	125 (few) 150-200	Gravenstein York Imperial Ben Davis Baldwin Jonathan Newtown Ortley	
Stockholm	1 Box 2. Barrel	1. Red 2. Yellow	150-200	York Imperial Ben Davis Baldwin Jonathan Spitzenburg Winesap Newtown	

Varieties Preferred

The first choice of apples in English markets is for the Newtown Pippin, which was a favorite of Queen Victoria, and is still known as the royal apple. However, prices for this variety are usually so high that consumption is confined to the well-to-do. The Cox Orange Pippin is also highly esteemed; and the demand being greater than the supply, the price is high. Frequently these choice apples, wrapped in cotton and packed in cartons, are used as gifts at Christmas and other seasons.

Most American varieties are salable in Great Britain, but comparatively few of the early varieties have been exported because of their perishable quality. Nevertheless, the shipments of these are increasing, considerable quantities of Gravensteins, Williams and McIntosh having been exported during the past season, 1925-26. For the most part exports are generally confined to later varieties, Baldwin being the principal one from New York and New England. From Virginia the York Imperial and Ben Davis, and from the Pacific Northwest the Jonathan, Winesap and Delicious are the chief exported varieties. Table 18 presents facts as to the preferences of chief European wholesale markets. These are compiled from "Foreign News on Apples," the reports of the foreign agent of the United States Department of Agriculture.

It will be noted that the Northwestern varieties, Jonathan, Spitzenburg and Winesap are those most generally preferred. The York Imperial is liked in almost every British market. The Jonathan is probably preferred in more European markets than any other American variety, being reported as a favorite in eleven of the eighteen markets from which information has been secured. As in our own markets, practically all foreign markets prefer red apples.

Sizes Preferred

The demand on the British markets is for apples of medium size, the larger sizes being penalized in some markets by a lower price. In general the markets in the northern part of the United Kingdom will use larger apples than will those of the southern part. Even here, however, the preference is for sizes varying from 2¼ to 2½ inches, or boxes containing 163 to 180 apples by count[1]. While apples as large as 150's will sell, they are frequently found to bring from 12 cents to 48 cents less per box. In the markets of the southern part of England and Wales, apples of 2 inches to 2¼ inches (216 to 234 per box) are preferred by most consumers.

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[1] The sizes of apples corresponding to the "count" of boxed fruit allow a variation of ⅛ inch above or below the stated diameters. A box containing 163 to 200 apples, for example, is supposed to contain apples of 2⅜ inches diameter, but they may vary from 2¼ to 2½ inches. The figures given below show the counts and approximate sizes with their allowable variations.

Count	Size (inches)	Count	Size (inches)	Count	Size (inches)
263)		150)		80)	
234)	2 to	138)	2½	72)	3¼
216)	2¼	125)	to	64)	to
		113)	2¾	56)	3¾
				48)	
200)		112)			
188)	2¼	104)	2⅞		
175)	to	96)	to		
163)	2½	88)	3⅛		

Since grades are fixed by color and condition as well as by size, it is not possible to add the corresponding grades to the above table. The Massachusetts grading law requires a certain percentage of color for certain varieties, for the different grades. The conditions as to blemishes also vary with the grade.

The reason assigned for this liking for small sizes is that most apples are sold by the pound. For eating "out of hand," families of moderate means desire to get about 5 apples to the pound. Obviously these must be of small size.

Extension of Markets

The possibility of extending the sale of apples in Europe is shown by the recent experience in Paris, where by judicious advertising and systematic distribution on the part of wholesalers in Rotterdam, considerable quantities of United States apples were sold during the late winter and spring of the season of 1925-26, after the bulk of the French crop was gone. Since the French like larger apples of better quality than those chiefly desired on British markets, apples from the United States have been unpopular in France because they have heretofore reached France by re-shipments from England. Direct shipments of larger sizes better graded would doubtless be well received in French markets. It is evident that barreled apples will not appeal to the French taste, as they are regarded as of poorer quality than boxed apples. The apples which sold so well in Paris in the spring of 1926 were all Northwestern boxed apples which had been held in storage by Dutch importers.

Much advertising of apples has recently been carried on by English agencies, but information as to the effect is not at hand.

PRICES

Unless the producer can obtain a fair profit, he can not long grow a product. Unless the dealer can make a fair profit, he will not long handle it, and unless the consumer can obtain a product at a fairly reasonable price, sales are likely to be much restricted. Information with reference to prices is, therefore, of the utmost importance to producers and dealers as well as to consumers. For purposes of this study the Boston market only is considered, and unless otherwise stated, the prices used are prices of A grade Baldwin apples on the Boston market. Statistics of prices of apples on foreign markets are, unfortunately, not available except for brief and irregular periods. It is, therefore, impossible to include a comparison of domestic and foreign prices.

Price Movements

A study of the movement of prices of apples shows two general types of fluctuations, based on the length of time considered: (1) the fluctuations which occur within the season, from the time the first early apples are placed on the market until the last of the crop is sold; (2) the variations from year to year, which are caused largely by the size and quality of the crop. There are price differences also in a season between the different varieties and grades of apples, due to the popularity and supply of certain varieties and the preference of consumers for certain grades; and this fact adds to the difficulty of comparing prices from year to year.

Various factors influence the price of any product, chief of which are the volume of the supply, the quality of the product, the demand, and the general level of prices.

No facts are available as to the quality of apples sold in Boston during the early part of the period covered by the statistics of production, 1889 to date, hence the influence of this factor can not be estimated.

Seasonal Fluctuations

With the exception of a few seasons since 1878 the price of apples has been higher at the end of the season than it was at the beginning. In general the price fluctuates more or less early in the season and then rises rather steadily as the season progresses. Now and then the price shows a decline at the end of the season, and occasionally there is little or no decline from the beginning to the end of the season.

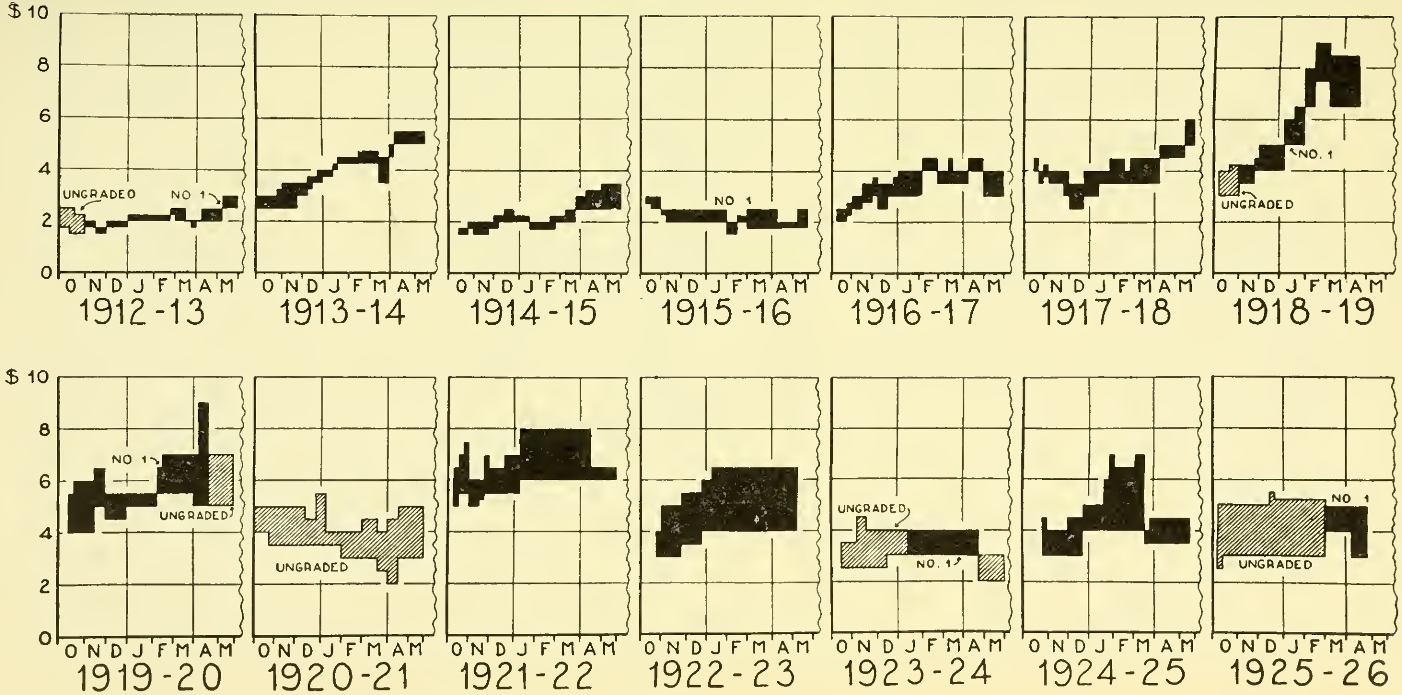
Since the average price of all varieties and grades of apples gives a true picture of none of them, it has been deemed best to study seasonal fluctuations of one variety which is on the market as much of the season as possible. For this purpose A grade Baldwin apples are chosen, and the average monthly prices for the period from 1878 to 1924 are presented in Table 19. For the purpose of comparison, average prices during the first 25 years and the last 25 years are separated from the rest of the period. During the 47 years included in the table the average price in May was $1.43 per barrel above the average for October, nearly 60 per cent increase during the season. During the last 25 years of the period, 1900-25, this increase was not so great, being but $1.39 or 49 per cent, although the prices ranged higher than in the first 25 years. This smaller variation between the October and May prices is due to the higher prices paid for apples during this later period, in accordance with the higher level of all prices, and to the improved storage facilities of the later years.

Table 19. Average Monthly Prices per Barrel of No. 1 Baldwin Apples

Month	47 years 1878-1924	25 years 1878-1903	25 years 1900-1925
October	$2.41	$1.88	$2.82
November	2.56	2.12	2.96
December	2.76	2.31	3.17
January	3.01	2.52	3.45
February	3.27	2.75	3.74
March	3.48	2.93	3.97
April	3.64	3.13	4.10
May	3.84	3.35	4.21
Average	**3.12**	**2.62**	**3.55**
Average increase—October to May	1.43	1.47	1.39

During the seasons of this period when the common movement was reversed and the price declined throughout the season, apparently the prices in the fall were too high and the crop could not be sold at the early

CHART 3. Range of Wholesale Prices of Baldwin Apples in Boston, 1912 to 1925. Prices of No. 1 Apples Are Shown, Except as Indicated. (Chart prepared by Professor D. W. Sawtelle, Department of Agricultural Economics, Massachusetts Agricultural College.)



figures. In several of the 47 seasons the prices fluctuated so that there was no definite movement either up or down.

Fluctuations from Year to Year

Those price fluctuations which are apparent from one year to another naturally show wider divergencies than do those within a season. The range for the period of 47 years was from $1.03 per barrel in 1896-97, to $6.71 in 1919-20, with an average of $3.36 per barrel. The low price of 1896 was due to an exceptionally large crop, especially in New England and New York, and to unusually low prices for all commodities. The season of 1919-20, as will be remembered, was one of generally high prices and of a short apple crop.

In Chart 3 is presented the range of yearly prices of Baldwin apples in Boston from 1912-13 to 1925-26. The period shows two distinct movements, the first from 1912-13 to 1918-19 having a comparatively narrow range between high and low prices of apples of the specified grade, and numerous fluctuations. The second movement from 1919-20 to 1925-26 is marked by fewer fluctuations but much wider range of prices. This difference between the two periods is apparently due to the increasing demand for apples of the better grades.

Baldwin and General Prices

In Chart 4 the index of prices of No. 1 Baldwin apples is compared with the index of the general price level for the period from 1890 to 1925. Previous to the war the price of apples fluctuated widely, more often above than below the level of general prices. During the war the two lines ran fairly close together; but the last few years have again seen wider fluctuations of the price of apples from the price of general commodities. The basis in both cases was the average of prices for 1910-1914.

Overproduction or short crops produce fluctuations in the prices of most farm products. Because orchards come into bearing only after several years of growth, these periodic fluctuations are much longer than with most crops. Orchardists should therefore find it profitable to study Chart 5 which shows the trend and fluctuations of Baldwin prices from 1889 to 1924. The movement in the years since 1913 is somewhat upward, although for the whole period of 36 years the trend is downward.

Baldwin and McIntosh Prices

Because statistics of production and commercial crops of the different varieties of apples are not available, it is impossible to offer explanations of the variations in prices of varieties from one year to another. The general trends of prices of Baldwin and McIntosh apples on the Boston and New York markets lie in the same direction. During the ten seasons from 1916-17 to 1925-26, the price of No. 1 McIntosh apples averaged 44 per cent higher on the Boston market than the price of No. 1 Baldwin apples during the months when the McIntosh was on the market. Considering the entire season, the prices of Baldwin apples averaged somewhat higher, but still much below the McIntosh. On the New York market the

CHART 4. Index of General Commodity Prices Compared with Index of Price of No. 1 Baldwin Apples, Boston Market, 1890-1925, Based on 1910-1914 Averages.

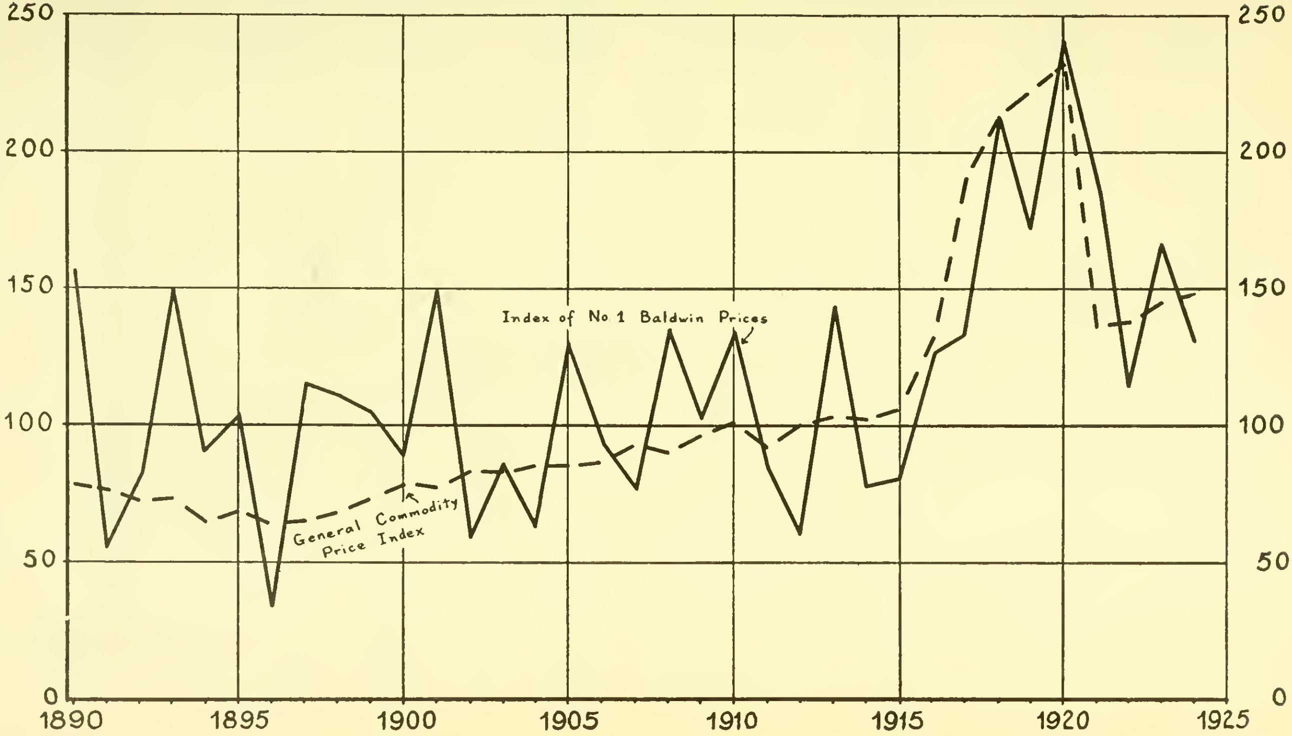
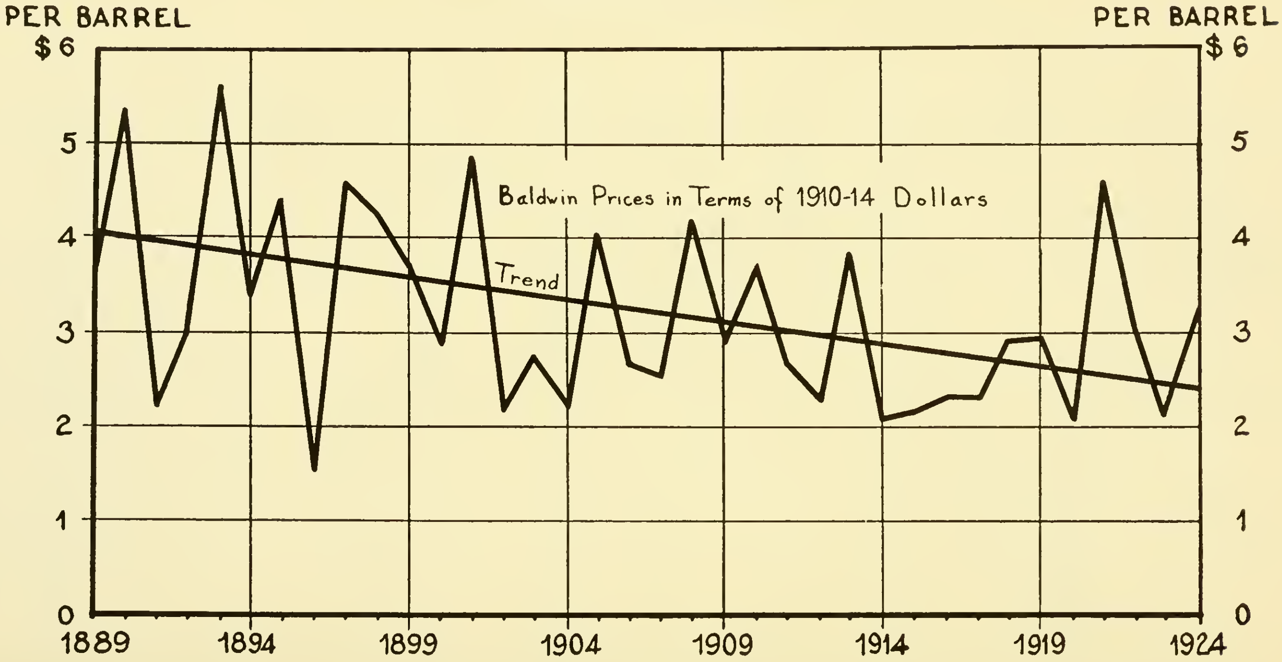


CHART 5. Price of Baldwin Apples in the Boston Market, 1889 to 1924, in Terms of the 1910-1914 Dollar.



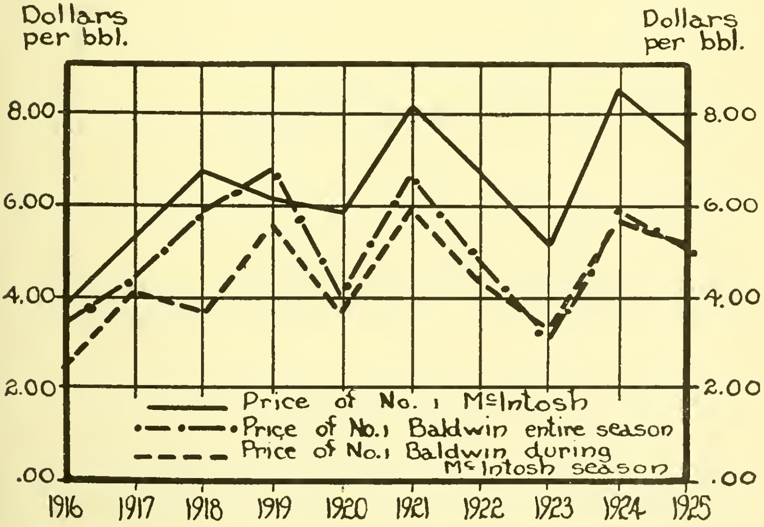
price of the McIntosh has averaged about 55 per cent above that of the Baldwins during the McIntosh season.

The season of the McIntosh has been recently much extended by storage, so that the Baldwin must compete with it for much more of the season than formerly. Prior to the season of 1922-23, McIntosh apples were seldom quoted on the Boston market after the Christmas season.

A large quantity of McIntosh of the 1925 crop was held in storage in Boston till late in February. When put on the market they brought from $2.50 to $2.75 in February to a trifle over $4.00 in April. Baldwin from cold storage during the same period ranged from $2.38 in February to $1.88 at the end of March.

A comparison of the prices of Baldwin and McIntosh apples on the Boston market appears in Chart 6. From 1916 to 1925 it is evident that the price of McIntosh has exceeded by a considerable sum the price obtained for Baldwin apples during the period while the McIntosh was on the market. It is apparent, also, that during the early years of this period the average price of Baldwin apples during the entire season was higher than while the McIntosh was available. But since 1922 these prices have run comparatively close together.

CHART 6. Comparison of the Prices of Baldwin and McIntosh Apples During the Time when McIntosh are on the Market and during the Entire Season, Boston Market, 1916-1925.

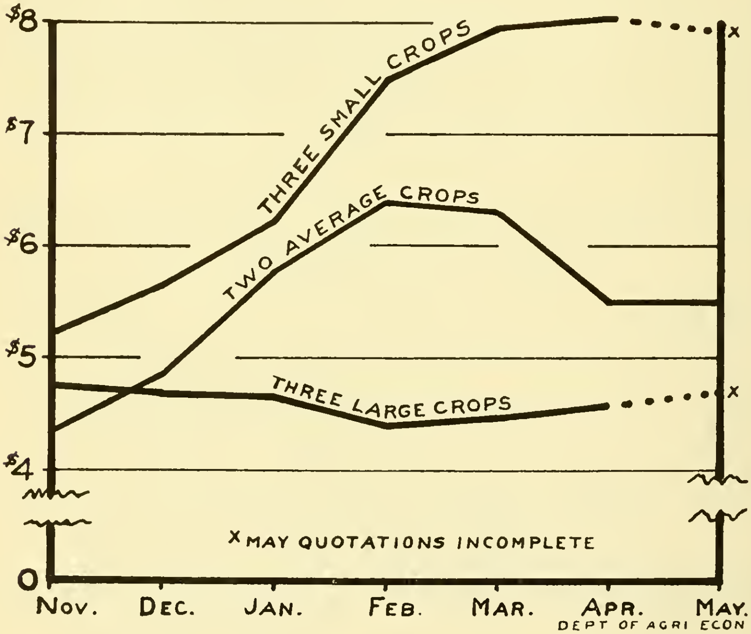


A similar comparison for the New York market shows a uniformly higher premium for McIntosh apples than on the Boston market and the same tendency toward uniformity of the prices of Baldwin apples during the McIntosh season and during the entire season.

Price and Size of Crop

The size of crop is a chief factor in determining the price of apples. For purposes of comparison commercial crops, 1918-1925, have been classified as average crops, large crops and small crops. On this basis it is evident (Chart 7) that prices in a season of average crop may be expected to rise rather steadily during the early part of the season and then either remain about stationary or show a slight decline at the end of the season.

CHART 7. The Top Prices of No. 1 Baldwin Apples, per Barrel, at Boston, 1916-1925, Arranged According to Small, Average and Large Crops.



In seasons of short crops the price rises rather steadily throughout the season, depending as in all cases somewhat upon the quality of the crop; the range of prices is likely to be considerably higher than in either of the other classes.

Seasons of large crops show a lower range in prices with a definite sag during the middle of the season, and perhaps a rise toward the end. It is obvious that the storage of apples tends to prevent slumps in prices by more equal distribution of the supply throughout the year.

CONCLUSIONS

1. The demand for New England apples is increasing in practically all markets of the state, this growing demand being greater for eating than for cooking varieties. During the last few seasons there has been a corresponding decline in receipts of apples from outside New England.

2. The demand for apples of good quality and uniform size is also increasing. Most dealers report little or no demand for anything but A grade fruit. As corollaries of this fact may be stated, (a) the need of better orchard practice in order to produce a higher proportion of A grade fruit; and (b) the demand for an outlet for fruit of poorer grade. How the latter shall be met is a matter for each grower to determine for himself.

3. Purchases by the pound are increasing. Whereas it is a matter of common knowledge that apples were formerly bought by the bushel and by the barrel, at present a considerable part of the volume consumed is bought by the pound or even by the apple. This fact must of necessity intensify the demand for good quality fruit, since customers are more exacting as to quality when purchasing but a small quantity at a time.

4. The demand is chiefly for the McIntosh as an eating apple. Dealers generally believe that only a small part of the possible demand for this variety is now supplied. In both Boston and New York many regard the possibilities of the extension of the market as practically unlimited.

5. The Baldwin is the variety chiefly in demand for cooking purposes.

6. The Greening, which is not popular in most markets of the state, finds ready sale in Fall River and New Bedford, and in some few of the smaller markets.

7. There is at present comparatively little advertising of New England apples. It is undoubtedly true that systematic advertising and distribution would bring about larger consumption. Such advertising might well be a part of the program of dealers, dealers' organizations, growers and growers' organizations. Successful advertising of California citrus fruits and of Cape Cod cranberries may serve as examples of efficient methods.

8. Bananas and oranges are the greatest competitors of apples on the Boston market.

9. Foreign markets absorb about 9 per cent of the average commercial crop of the United States. It is evident that failure of this outlet for our apples would result in disaster to the industry. Careful attention on the part of growers and shippers to the demand of foreign markets is imperative if the export trade is to be preserved. The competition from other exporting countries is increasing. If the United States is to hold her place as an exporter in these markets, it will be done by meeting the demands of these markets better than they can be met by apples from other sources. The foreign apple crop, including few dessert apples, is composed mostly of apples which compete with the bulk of shipments from the New England states and from New York. The increased use of cold storage in England will prolong the period when English apples are available.

10. In foreign as well as in domestic markets there is need of better sorting and grading of apples, since the foreign demand for fruit of good quality is also increasing.

11. For the foreign market greater care should be taken about arsenic spray residue, particularly in the case of shipments to the United Kingdom. Either the late spray now in common use should be abandoned or the fruit should be carefully cleaned before packing.

12. Careful packing in order to insure placing the apples in good condition on foreign markets is to be desired. The greatest loss in exporting apples is usually due to slack packages.

13. Because of the better storage facilities, some of the more popular varieties are on the market for a longer period than formerly, and in consequence prices of other varieties are held to a lower level. The effect of the McIntosh upon the Baldwin price is the best example of this influence.

14. Storage facilities likewise tend to decrease the seasonal fluctuations in prices of all varieties.

15. The size of the crop is the chief factor in determining prices of apples. If the crop is small the price ranges higher than if the crop is of average size, with a tendency to rise toward the end of the season. If the crop is larger than the average, the price tends to range lower than in other seasons, with less variations throughout the season.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 232 FEBRUARY, 1927

EFFECT OF POTASH SALTS ON CROP YIELDS

By SIDNEY B. HASKELL

Occasionally better table quality of potatoes, but seldom any significant difference in yields; variations in the stand of grass and clover, but surprising similarity in yields of hay; a distinct difference in the winter-killing of cane fruits, with consequent large differences in yield; no indication of sulfur shortage even after thirty years of treatment with little or no sulfur in the fertilizer, and a similar result with magnesium,—these are among the more important results of long-continued experiments comparing chemical forms of fertilizer potash, as reported in this bulletin.

Requests for bulletins should be addressed to

AGRICULTURAL EXPERIMENT STATION
AMHERST, MASS.

EFFECT OF POTASH SALTS ON CROP YIELDS

By Sidney B. Haskell

The response of a crop plant to the use of fertilizer potash may be influenced by a number of factors:—by the kind of plant and character of the soil; by the condition of the soil as influenced by cropping system followed; by tillage; by the kinds and amounts of other fertilizers applied; by the extent to which animal manures have been used; and possibly by the particular potassium salt applied. Moisture conditions in the soil during the growing season may have an influence, first on the need of fertilizer potash, and secondly on the relative value of the different sources; and so also may the time of the year (early or late in the growing season) in which the crop is planted or makes its most luxuriant growth.

Data which bear on some of these problems have been accumulated over a period of many years at the Massachusetts Agricultural Experiment Station. Crop yields from three experimental fields contribute to our knowledge of the need of potash by plants growing under a soil management system which does not include the use of animal manures. Data from other fields add to our knowledge of the relative effect of sulfate versus muriate of potash, of the possible role of sulfur as an "essential" plant food, and of the influence of magnesium when applied as an ingredient of the fertilizer mixture.

History of Fields

The fields above referred to are known in the Station publications as the North and South Soil Tests, Field B (comparing muriate with sulfate of potash), Field G (comparing six different carriers of potash), and Field A (comparing different sources of fertilizer nitrogen, with an incidental comparison of muriate of potash with sulfate of potash-magnesia). Full descriptions of these fields and the experiments carried on have been given repeatedly in Station publications.[1]

Soil Conditions

All of the soil of the older part of the Experiment Station farm is classified by the United States Bureau of Soils as the Merrimac. This is a soil of glacial terrace formation, locally much modified by the action of wind and water. The surface soil is fairly uniform, but the subsoil may be highly variable. There are also local variations which occur in areas too small to receive separate classification. Physical analysis of soil samples drawn from four of these five fields gives the following results:[2]

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[1] Specifically, reference is made to the following:

For the North and South Soil Tests, Mass. Agr. Expt. Sta. Bul. No. 212.
For Field A, Mass. Agr. Expt. Sta. Bul. No. 204.
For Field B, Mass. State Agr. Expt. Sta. Repts. 1884 to 1894, inclusive; Mass. (Hatch) Agr. Expt. Sta. Repts. 1896 to 1919, inclusive.
For Field G, Mass. (Hatch) Agr. Expt. Sta. Repts. 1900 to 1920, inclusive.

Physical Analysis of Soils

Field	Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Silt	Clay
Field G							
Surface Soil	0.47	1.12	1.58	5.26	60.64	26.58	4.36
Subsoil	1.00	2.48	2.41	6.65	48.30	29.20	9.96
Field B							
Surface Soil	1.35	3.98	2.71	5.98	62.67	19.72	3.56
Subsoil	4.02	6.33	4.16	9.17	55.50	19.82	1.00
North Soil Test							
Surface Soil	0.42	1.19	1.34	7.21	61.83	24.43	3.58
Subsoil	0.68	1.32	2.15	15.71	63.05	15.69	1.89
South Soil Test							
Surface Soil	1.71	2.28	1.52	10.23	54.82	26.70	2.74
Subsoil	3.10	4.40	2.16	8.99	48.09	30.79	2.46

The surface soil samples were taken down to plow depth, those of the subsoil to a depth of thirty inches. According to the modified scheme of textural classification as developed by Dr. A. B. Beaumont,[3] these soils would all be classified as sandy loams.

While the above soils are similar in physical characteristics, yet they are subject to wide differences in moisture supply. Field G lies in a hollow, is relatively poorly drained, and has a stiff subsoil of a character inadequately portrayed by physical analysis. In its moisture relations Field A is almost ideal, while progressively Field B and the two Soil Tests are somewhat subject to drouth.

Work on these five fields was instituted years ago—that on the Soil Tests and Field G under the leadership of former director William P. Brooks; that on the other fields mentioned, by the late Dr. C. A. Goessmann.

The Need for Fertilizer Potash

Need for fertilizer potash may be considered as synonymous with plant response to the application of potash fertilizers. Crops grown in the Soil Tests above referred to show distinct response to such application. That such response was influenced by the kind of crop being grown was evident, but the number of times a given crop was grown was too small to permit a safe generalization as to the relative potash-foraging ability of different plants. The following table abstracted from Bulletin No. 212 shows the crop returns per acre from the use of potash under conditions where manure was not applied:—

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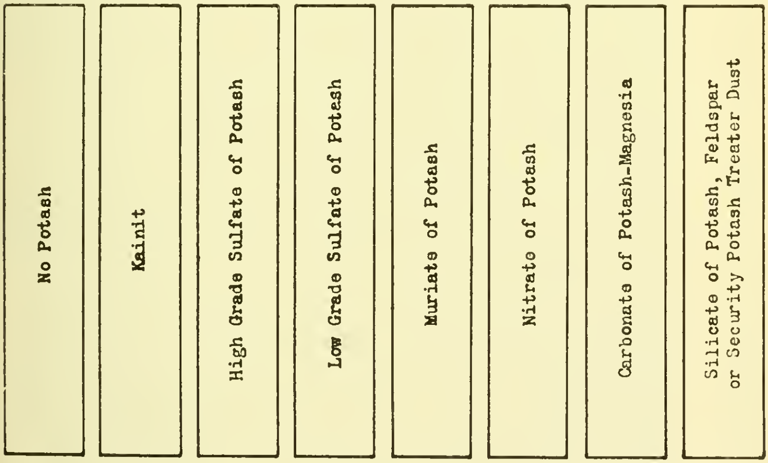
[2] The analyses were made by Mr. O. W. Kelly of the Department of Agronomy of this institution.

[3] Jour. Amer. Soc. Agron. v. 18, No. 3, pp. 238-216,

Effect of Use of Fertilizer Potash

Fertilizer other than Potash	South Soil Test				North Soil Test			
	Corn (10 crops)				Grass and Clover (6 crops) Pounds per Acre			
	Grain, Bushels per Acre		Stover, Pounds per Acre		Unlimed Half		Limed Half	
	Without Potash	With Potash	Without Potash	With Potash	Without Potash	With Potash	Without Potash	With Potash
None	14.08	38.22	1393	3399	808	1017	1708	3660
Nitrate of Soda	16.39	38.72	1680	3192	2043	1872	2490	3498
Acid phosphate	14.24	47.12	1545	3796	1147	815	1407	3967
Nitrate of soda and acid phosphate	21.09	52.19	1820	4019	2285	2447	3617	4872

Actual measurement of crop response to fertilizer potash is also made on Field G. This is the best laid out of the older field experiments of the Station, with plots one-fortieth of an acre in area and treatments replicated five times. The plan of a single series out of the five, precisely similar to the other series, is shown in the diagram given below. In addition to potash sources listed, an eighth plot received at different times silicate of potash, feldspar and Security Potash Treater Dust. Because of this varied treatment, results from this last plot are not presented in this report.


No Potash
Kainit
High Grade Sulfate of Potash
Low Grade Sulfate of Potash
Muriate of Potash
Nitrate of Potash
Carbonate of Potash-Magnesia
Silicate of Potash, Feldspar or Security Potash Treater Dust

The annual fertilizer treatment was as follows:

Nitrate of soda,	250 pounds per acre
Tankage,	270 pounds per acre
Acid phosphate,	360 pounds per acre

In addition, 135 pounds per acre of potash (K2O) were applied annually in six different carriers, up to and including 1916, this amount being reduced in 1917 and succeeding years to 81 pounds per acre. All the fertilizer was spread in a single annual application, usually broadcast before planting save in the case of grass and clover, where it was applied as a top dressing. On the nitrate of potash plots the amount of nitrate of soda was reduced to compensate for nitrogen applied in the potash carrier.

The testimony of two adjacent experimental fields indicates that crop yields were not limited by lack of nitrogen and phosphorus. The large amount of nitrate of soda applied may conceivably have served to decrease need for applied potash, in which case response to the use of fertilizer potash was of a different magnitude from that which otherwise might have been secured.

The weighted per centum yields of all crops grown on potash treated plots during the progress of the test, excluding only corn stover and the straw of grains and of soy beans, are as follows (the yields on the no-potash plots taken as 100): Series 1, 112.4 per cent; Series 2, 110.6 per cent; Series 3, 110.2 per cent; Series 4, 134.9 per cent; Series 5, 131.2 per cent. Variation between series, as indicated by the average response to potash of all potash-treated plots within the series, is high. The cause of this variation is now under investigation. For the present we must assume that each check, in each series, is truly representative of the plots concerned. This assumption, naturally, cannot be proven.

Varying Response of Different Crops to the Use of Fertilizer Potash

The four crops grown a sufficiently large number of times to make results of value—namely, corn, soy beans, potatoes, and grass and clover—show a widely varying response to the use of potash. The following table summarizes the data, respectively for Series 1, 2 and 3 on which potash gave but a small response for most of the crops, and for Series 4 and 5 where the response was larger than the average for all crops.

Response of Different Crops to the Use of Fertilizer Potash
No Potash = 100

Crop	Series 1, 2, 3		Series 4, 5		Whole Field	
	No. of Comparisons	*Percentage Yield*	No. of Comparisons	*Percentage Yield*	No. of Comparisons	*Percentage Yield*
Corn						
grain	10	*97.7*	7	*133.8*	17	*109.6*
stover	10	*127.3*	7	*176.6*	17	*143.3*
Soy Beans						
seed	12	*101.5*	5	*113.4*	17	*104.9*
straw	12	*102.3*	5	*108.8*	17	*104.2*
Potatoes	15	*122.0*	10	*165.5*	25	*136.3*
Grass and Clover						
hay	21	*108.9*	14	*122.0*	35	*113.5*
rowen	21	*129.0*	14	*167.8*	35	*141.1*

Potash gave a significant increase in yield of potatoes on all series, differing markedly from soy beans which not only did not respond at all on Series 1, 2 and 3, but which gave response in but a single year, on a single series (4), for the rest of the field. The yields of both potatoes and soy beans were at least fair, as will later be shown. The inability of the potato to forage for its potash, and the very great ability of the soy bean to make use of the natural supply of the soil, are both plainly evident.

Corn failed to give consistent increase in grain except on the last two

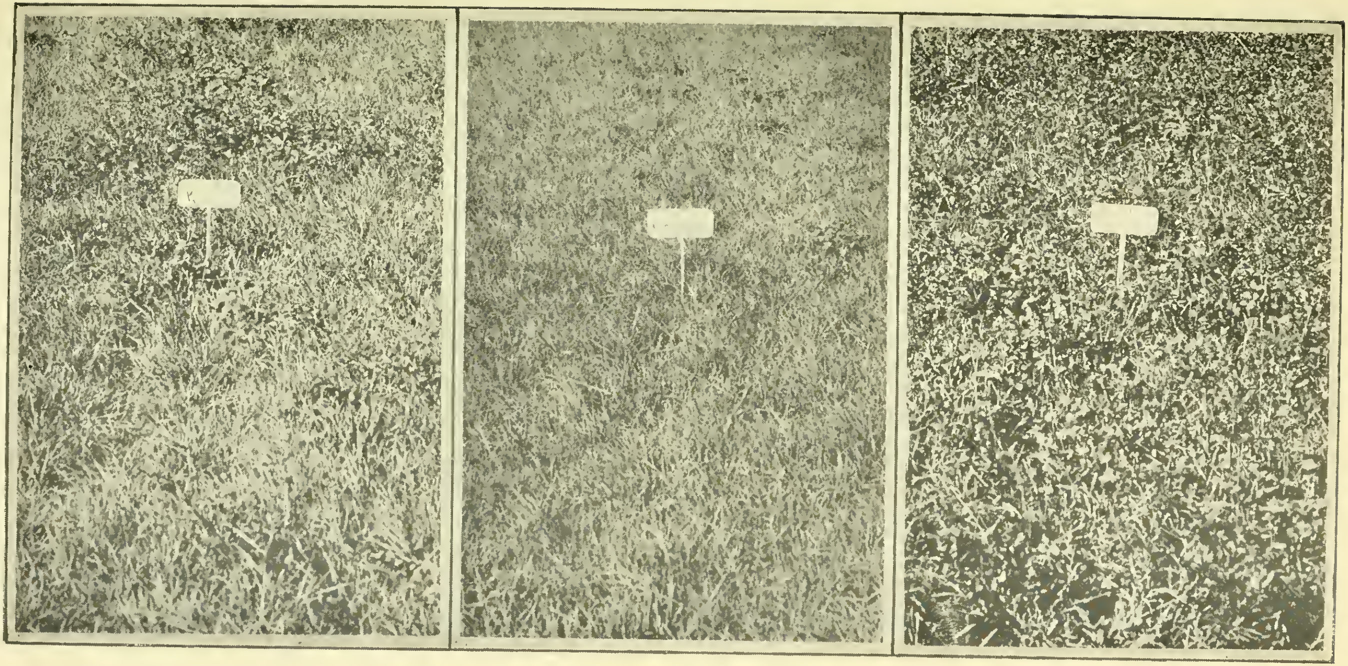


PLATE I. Effect of Potash and of Form of Potash on Clover Rowen.

Seed Mixture: Timothy, Redtop, Red and Alsike Clovers, sown in August two years before.

Left—Kainit, yield 800 pounds per acre. Center—No Potash, yield 240 pounds per acre. Right—Sulfate of Potash, yield 2360 pounds per acre.

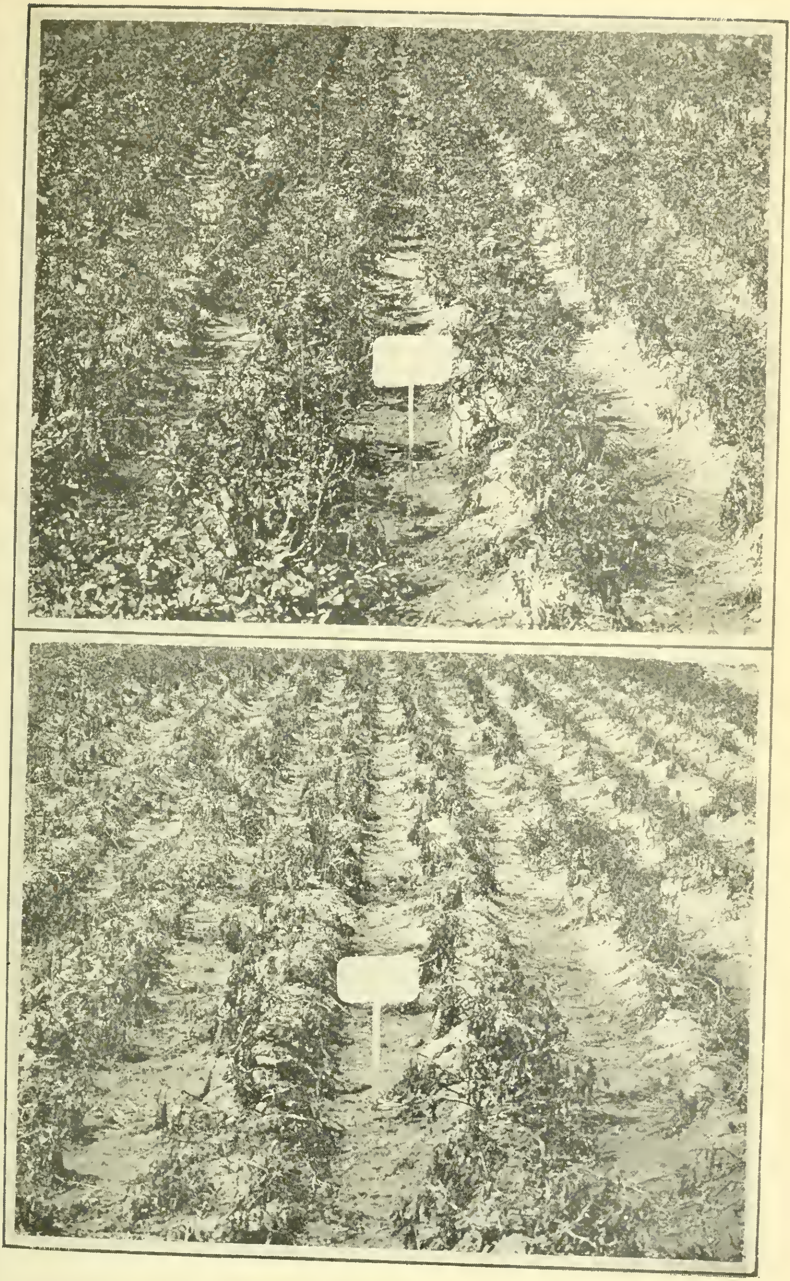


PLATE II. Green Mountain Potatoes.
Top—High Grade Sulfate of Potash, yield 268 bushels per acre.
Bottom—Muriate of Potash, yield 216 bushels per acre.
Photograph taken September 16.

One of the years when sulfate was better than muriate.

series, and the experience with the hay crop was surprisingly similar. Without exception, however, the stover responded to the use of potash, and the rowen crop responded even on Series 1, 2 and 3. Both observation and photographic record show that, following a new seeding, the first cutting consisted largely of grass; while the second cutting, or rowen, was mainly clover. Plate I illustrates this dependence of clover, as grown under the conditions of the experiment, on fertilizer potash.

Comparison of Different Potash Carriers

Comparison is made in the following table for corn, soy beans, potatoes, and grass and clover, all of which crops were grown a sufficient number of times to make the average results of significance.

Comparison of Different Potash Carriers

Average Yields per Acre

	Number of Comparisons	No Potash	Kainit	H. G. Sulfate	L. G. Sulfate	Muriate	Nitrate	Carbonate of Potash-Magnesia
CORN:								
Grain, bushels								
Series 1, 2, 3	10	60.9	58.4	59.6	62.6	61.2	57.1	57.1
Series 4, 5	7	42.3	56.3	58.4	58.0	53.7	56.0	56.9
Whole Field	17	53.2	57.5	59.1	61.3	58.1	56.6	57.0
Stover, pounds								
Series 1, 2, 3	10	4408	5708	5532	5308	5628	5696	5800
Series 4, 5	7	3029	5331	5463	5017	5663	5097	5531
Whole Field	17	3840	5553	5504	5188	5642	5449	5689
SOY BEANS:								
Seed, bushels								
Series 1, 2, 3	12	26.9	23.4	27.1	27.7	27.4	28.6	29.7
Series 4, 5	5	25.3	27.3	30.3	29.4	26.6	27.9	30.8
Whole Field	17	26.4	24.6	28.0	28.2	27.2	28.4	30.0
Straw, pounds								
Series 1, 2, 3	12	2163	2007	2230	2130	2163	2419	2322
Series 4, 5	5	2172	2256	2448	2204	2140	2544	2588
Whole Field	17	2166	2080	2294	2152	2156	2456	2400
POTATOES: bushels								
Series 1, 2, 3	15	192.0	216.1	236.7	233.4	238.2	238.1	243.0
Series 4, 5	10	140.3	200.7	235.4	234.6	238.6	236.1	247.5
Whole Field	25	171.3	209.9	236.2	233.9	238.4	237.3	244.8
GRASS AND CLOVER:								
Hay, pounds								
Series 1, 2, 3	21	4685	5066	4982	5263	5095	5316	4885
Series 4, 5	14	3793	4367	4489	4376	4767	5003	4551
Whole Field	35	4328	4786	4785	4988	4964	5191	4751
Rowen, pounds								
Series 1, 2, 3	21	1236	1392	1499	1648	1593	1749	1688
Series 4, 5	14	836	1117	1356	1477	1404	1555	1511
Whole Field	35	1076	1282	1442	1579	1517	1671	1617
Total crop, pounds								
Series 1, 2, 3	21	5921	6458	6481	6911	6688	7065	6574
Series 4, 5	14	4629	5483	5846	6052	6172	6558	6061
Whole Field	35	5404	6068	6227	6567	6481	6862	6368

The following facts are outstanding:

1. Kainit was used less successfully than any other source of potash. On soy beans there was an apparent decrease in crop resulting from its use. This material is essentially low-grade. To secure an amount of potash equivalent to that in 270 pounds per acre of the muriate, over 1000

pounds of kainit must be applied. Conceivably, too much of soluble salts may have been applied and resulting injury may have overbalanced increases which might otherwise have been produced.

2. The remaining sources of potash were about equally effective. Differences in yields arising from their use are well within the limits of experimental error. There were neither markedly injurious nor beneficial results from the use of any one of these as compared to the others.

Muriate versus Sulfate of Potash

The most important of the comparative data just presented are those which bear on the use of muriate of potash versus the sulfate, these two being standard sources of fertilizer potash. In addition to these data there are many from Field B, devoted to a comparison of these two salts. This field was originally laid out in 1883; and was formally devoted to a comparison of these salts in 1893, with records from that year which are considered trustworthy and fairly representative of normal experience. Fertilizer other than potash consisted of 600 pounds per acre of fine ground bone. At the beginning potash was applied at the rate of 400 pounds per acre of muriate, or the same quantity of sulfate. These amounts were reduced in 1900 to 250 pounds per acre; and further reduced in 1917 to 150 pounds per acre. There were five pairs of differentially treated plots, not cropped in definite rotation.

The following table summarizes the more significant results, and presents averages from Field G for comparison.

Comparison of Muriate of Potash with High-Grade Sulfate of Potash

Average Yields per Acre

	Crop	Field	Number of Comparisons	Muriate	Sulfate
SEEDS AND GRAINS	Corn, grain, bus.	B	9	59.2	60.4
		G	17	58.1	59.1
	Corn, stover, lbs.	B	9	6295	5626
		G	17	5642	5504
	Soy Beans, seed, bus.	B	6	18.9	21.3
		G	17	27.2	28.0
	Soy Beans, straw, lbs.	B	6	2238	2346
		G	17	2156	2294
FODDER CROPS, GREEN	Clover, lbs. (Red, Mammoth and Alsike)	B	4	23144	23308
FODDER CROPS, DRY	Alfalfa, total lbs.	B	9	6508	7113
	Clover, total lbs. (Red, Mammoth and Alsike)	B	16	6534	6453
	Grass and Clover, hay, lbs.	G	35	4964	4785
	rowen, lbs.	G	35	1517	1442
VEGETABLES AND ROOTS	Asparagus,[a] lbs.	B	12	4916	3875
	Cabbages, lbs.	B	10	32387	34017
		G	7	44154	41800
	Mangels, lbs.	B	3	38897	35141
		G	1	35600	32400
	Potatoes, bus.	B	9	221	233
		G	25	238	236
	Squash, lbs.	B	4	13709	13694
FRUITS	Blackberries,[a] lbs.	B	12	2692	3916
	Currants,[b] lbs.	B	6	1086	906
	Raspberries,[b] lbs.	B	13	1498	1857
	Rhubarb,[b] lbs.	B	14	19021	22916

[a] One planting.

[b] Two plantings.

A word of warning may be necessary to guard against attaching undue significance to differences in crop yields of perennials. The initial error which may have been caused by unconscious selection of plants is perpetuated through the years. Repeated takings of the product of a single planting do not in such case constitute effective replication of the experiment.

The results as a whole show significant differences in yield arising from the comparative use of these two salts only in the case of the winter-tender cane fruits, raspberries and blackberries. There were, however, certain other differences evident from time to time. In some years potato tops on the muriate plots "went down" a week or ten days earlier than did those on the sulfate. Raspberries and blackberries showed great differences in yield following those seasons in which winter-killing was serious. Whether this was a protective influence of the sulfate of potash, or a reverse influence of the muriate, is not evident, and is now a matter of study. Growth of clover on sulfate of potash was often better than on the muriate, but with differences seldom shown in yield owing to the fact that increased weed growth made up for weight of crop lost when clover failed. In certain years, also, there was betterment in the table quality of potatoes from sulfate of potash. A number of analyses of starch were made in an endeavor to correlate the presence of this carbohydrate and the potash salt used. Differences in starch content were found to be of little significance and not correlated with the quality of the tuber.

These relatively minor although sometimes important differential effects of the several potash salts are difficult to measure. Plates I and II, however, show these in a visual way for grass and clover and for potatoes.

Effect of Sulfur

In view of the fact that sulfur is occasionally deficient in soil and when so deficient ranks as an "essential" plant food, comparison of average yields under sulfur versus no sulfur treatments is of value. As calculated from average analyses, there were applied on the sulfate of potash plots 184 pounds per acre of sulfur trioxide annually from 1894 through 1899, 115 pounds annually from 1900 through 1916, 69 pounds annually beginning in 1917. On the muriate of potash plots, however, no sulfur was used save the very small amount contained in the bone, which is estimated at 1-10 of 1 per cent, or slightly more than half a pound of sulfur trioxide yearly. We do not know the amount which comes down annually with precipitation. In any case, this amount must be similar on the plots under discussion. Average yields of most of these crops as secured during the course of the experiment have already been given. Owing to lack of definite cropping system, it is impracticable to measure tendencies by comparing crops grown in recent years with those produced at an earlier date, presumably before sulfur shortage, if any, had become serious. The yields in the last five-year period prior to changing the concept of the experiment, representing as they do the influence of twenty to twenty-five years of sulfur versus no sulfur differential fertilization, do, however, throw light on the question. There is no evidence that shortage of sulfur has been reducing yields; nor that the sulfur in sulfate of potash was of significant value to the crop. The yields follow:

Effect of Sulfur on Crop Yields (Field B)

Yields per Acre

Year	Plots	Crop	Muriate	Sulfate
1914	17 and 18	Squash, lbs.	15886	13940
	18 and 19	Potatoes, bus.	168.0	148.2
1915	11 and 12	Potatoes, bus.	215.2	219.0
	17 and 18	Mangels (roots and tops), lbs.	66520	62782
	19 and 20	Alfalfa, total lbs.	9358	9552
1916	11 and 12	Soy Beans, beans, bus.	29.9	32.0
		straw, lbs.	3616	3675
	17 and 18	Corn, grain, bus.	49.1	52.1
		stover, lbs.	4221	4603
	19 and 20	Alfalfa, total lbs.	9392	8790
1917	11 and 12	Soy Beans, beans, bus.	14.1	14.9
		straw, lbs.	3805	3870
	17 and 18	Mangels (roots and tops), lbs.	21229	18492
	19 and 20	Alfalfa, total lbs.	8076	8726
1918	11 and 12	Squash, lbs.	15349	18166
	19 and 20	Corn, grain, bus.	86.6	81.5
		stover, lbs.	9358	7759

Effect of Magnesium

Mention has already been made of the comparison of the so-called low-grade sulfate of potash with other potash carriers, on Field G. In addition this potash carrier is compared with the muriate on certain plots of Field A. The following table summarizes results:—

Comparison of Muriate of Potash with Sulfate of Potash-Magnesia

Average Yields per Acre

	Crop	Field	Number of Comparisons	Muriate of Potash	Sulfate of Potash-Magnesia
SEEDS AND GRAINS	Corn, grain, bus.	A	20	71.7	73.0
		G	17	58.1	61.3
	Corn, stover, lbs.	A	20	6340	5960
		G	17	5642	5188
	Millet, seed, bus.	A	4	27.5	29.8
	straw, lbs.	A	4	5474	4881
	Oats, grain, lbs.	A	12	1343	1378
	straw, lbs.	A	12	3539	3355
	Rye, grain lbs.	A	3	1287	1347
	straw, lbs.	A	3	3530	3587
	Soy Beans, seed, bus.	A	8	22.1	25.3
		G	17	27.2	28.2
	Soy Beans, straw, lbs.	A	8	2094	2061
		G	17	2156	2152
FODDER CROPS, GREEN	Ensilage Corn, lbs.	G	5	39754	38822
	Soy Beans, lbs.	A	8	14344	13570
FODDER CROPS, DRY	Canada Field Peas and Oats, hay, lbs.	A	4	6250	5875
	Corn fodder, lbs.	A	3	6029	5683
	Grass and clover, lbs.	A	26	5830	5966
		G	35	6481	6567
	Millet hay, lbs.	A	4	9450	9213
	Oat hay, lbs.	A	8	3038	2525
VEGETABLES AND ROOTS	Cabbages, lbs.	G	7	44154	44629
	Potatoes, bus.	A	18	227.2	251.5
		G	25	238.4	233.9

On both Field A and Field G an acidulated phosphate was used as a source of phosphorus; and in certain comparisons on the former field, sulfate of ammonia was the source of nitrogen. It is probable that in these plant food carriers sufficient sulfur has been applied to meet any deficiency which there may have been in the soil. If this is the case, it follows that the comparisons in question are at least a fairly adequate measure of the influence of magnesia. The results of these comparative tests give no great support to the contention that magnesium is deficient in our soils, and hence should be applied in fertilizer form. The experience on Field G, with potash-magnesium carbonate compared with other potash carriers, still further supports this view. It is true that some magnesium may have been applied in lime; but analytical records show the amount to have been so small as to be of no possible significance.

Summary

The more outstanding results of these long-standing field experiments are summarized as follows:

1. When used on a sandy loam soil in a cropping system which did not include the application of animal manures, fertilizer potash was found to have a significant effect on crop yields.

2. Crops varied in response to use of this plant nutrient. Potatoes were very responsive; corn less so, but in stover markedly responsive; soy beans, even on soil known to be potash hungry, were almost independent of applied potash. Used on a mixture of grass and clover, the effect of fertilizer potash in increasing the proportion of clover was marked.

3. Difference in yield of crops as produced by the comparative treatment with different potash salts was found to be comparatively small, the single marked exception being the cane fruits.

4. When used on cane fruits, winter injury to the canes was much more serious with muriate the source of potash than with sulfate. This difference was reflected in yield of crop.

5. There was a difference in the quality of potatoes grown on muriate versus sulfate of potash.

6. Few indications of crop limitation on account of lack of sulfur were found, even after twenty-five years of cropping with a "no-sulfur" fertilizer mixture.

7. The magnesium of sulfate of potash-magnesium was found to have little influence on yield of crops.

Publication of this Document Approved by the Commission on Administration and Finance

3000. 2-'27. Order. 8080.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN 233 MARCH, 1927

THE CODLING MOTH IN MASSACHUSETTS

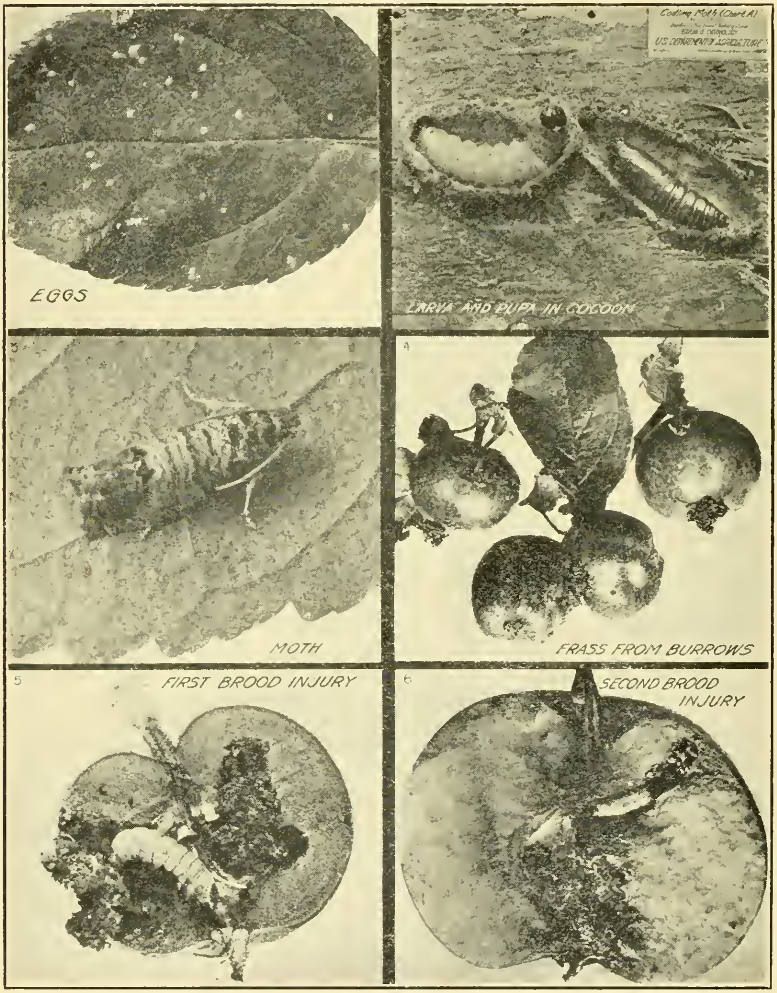
By A. I. Bourne and W. D. Whitcomb

In an attempt to find how to prevent the so-called "side worm" injury of apples, arising from attack of the codling moth, the Experiment Station has studied the life history of this moth for three consecutive seasons. This bulletin reports results, and presents graphic illustrations showing the periods at which infestation leading to side worm injury is most probable. A spray calendar, with treatments recommended against both insect and disease, is included.

Requests for bulletins should be addressed to the

AGRICULTURAL EXPERIMENT STATION
AMHERST, MASS.

Plate I. Life History of the Codling Moth, Showing Different Stages and Injury to Fruit. (From U. S. Department of Agriculture).


Codling Moth (Chart A)
BUREAU OF ENTOMOLOGY
U.S. DEPARTMENT OF AGRICULTURE
EGGS
LARVA AND PUPA IN COCOON
3
MOTH
4
FRASS FROM BURROWS
5
FIRST BROOD INJURY
6
SECOND BROOD INJURY

THE CODLING MOTH IN MASSACHUSETTS

By A. I. Bourne and W. D. Whitcomb

Importance as a Pest of Apples

The codling moth *(Carpocapsa pomonella* L., Order—Lepidoptera; Family—Eucosmidae) is a heritage of the modern fruit grower. Although a native of southeastern Europe, this insect has now been established in this country for nearly a century, and its increasing destructiveness has closely paralleled the development of the commercial apple growing industry in the United States. Estimates of the annual loss caused by the "apple worm" in this country approach twenty million dollars and Massachusetts fruit growers pay a proportionate share. It is generally considered to be the most destructive insect enemy of the apple in the world, and much of our present knowledge of orchard spraying has resulted from efforts to reduce the losses caused by this pest.

In Massachusetts and other Northern States, the codling moth is less abundant than in warmer regions, but even here it frequently damages 5 to 15 per cent of the apples in sprayed orchards and 40 per cent or more on neglected trees.

Food Plants

The apple is the favorite food of the codling moth. All varieties are attacked, but in this State a slight preference is shown for early maturing varieties such as the Williams and Gravenstein. Sweet or mildly acid varieties like the Delicious and Hubbardston appear to be favored. The Baldwin also becomes badly infested. This insect also breeds readily in crab apples, wild apples, and hawthorn fruits. Pears, especially the Bartlett, Clapp's Favorite, and Seckel are usually so severely attacked as to warrant the use of control measures. Feeding in peaches, plums, cherries, and quinces is common, particularly when they are grown adjacent to infested apples or pears. In California, the codling moth is a serious pest of English walnuts.

Nature of Injury

The larva, or "apple worm" as it is often called, is the only injurious form of the codling moth. It burrows through the fruit, causing it to ripen prematurely, to decay rapidly, and to be unmarketable as fresh fruit. The typical wormy apple resulting from the feeding of the codling moth larva in the fruit needs no description. In Massachusetts, the majority of the first worms to attack the fruit enter inconspicuously through the calyx cavity and leave it through the side. The round exit hole is very noticeable. Other worms, particularly late in the season, both enter and leave through the side, inflicting prominent damage.

A less important type of injury is caused by worms which, having eaten into the side of the fruit a distance of one-eighth of an inch or less, have been killed by birds, other insects, or poison, or have been dislodged by wind or rain. Such injury usually heals quickly and is called a "sting". However, the resulting scar materially reduces the value of the fruit.

Description and Habits

Fruit growers should be able to recognize the codling moth in its different stages of growth, in order to follow its development through the season and to understand the fundamental principles of its control.

The Moth. (See Plate I.) The adult moth is comparatively small, the female having a wing spread of about three-fourths of an inch, and the male slightly less. The fore wings are brownish gray crossed by numerous dark lines, giving a characteristic "watered silk" appearance. Near the tip is a large bronze-colored spot or band. The hind wings are light grayish-brown, becoming slightly darker toward the margin. Because of its size, color, and markings, the moth is quite inconspicuous when at rest, and consequently seldom observed in the orchard.

Of the moths which emerge first in the spring, males slightly predominate but, over the season as a whole, the number of males and females is approximately the same.

The moths as a rule remain quiet during the day and in cold, wet or cloudy weather, becoming active at dusk. The number of eggs per female moth varies greatly and is strongly influenced by sudden changes in temperature. Although the earliest emerging females may deposit very few eggs, the average number is twenty to twenty-five. In midsummer when more uniform and favorable weather prevails, the average number increases to thirty or forty.

The length of life of the moths varies according to sex and, to a considerable degree, according to the time of year they appear. In cold weather, activity is slight and the moths live from two to three weeks. Under favorable weather conditions, they become more active and the length of life correspondingly shortens. The average life of spring moths as observed in 1924 and 1925 according to the time of emergence was as follows:

Date of Emergence	Length of Life, Days	
	Males	Females
May 25—June 5	13—16	18—21
June 6—June 15	12—13	14—15
June 16—June 30	8—9	10—12

There is no such wide variation shown by the summer brood of moths where the average life of the males is eight to ten days, and of the females eleven to twelve days.

The Egg. The eggs resemble small oval discs, pearly white in color, and about the side of a pin head. They are deposited singly on the leaves, twigs or fruit, where they appear as milky white spots (See Plate I.). A few days after they are laid, the developing embryo is seen as a faint red ring, which gradually widens and deepens in color. A day or two before hatching, a conspicuous black spot, the head and thoracic shield of the larva, appears near the margin.

The Larva. (See Plate I.). The newly-hatched larva is about one-sixteenth of an inch long, pale greenish-white in color, with a shining black head much wider than the rest of the body. Upon emerging from the egg, the young worm crawls about over the leaf surface or fruit, in search of food and also protection from bright sunlight. If fruit is not immediately at hand, it usually crawls to the lower side of the leaf close to one of the main veins and either burrows into the vein or feeds on the leaf tissue close by, covering itself with a covering of silk. Here it may remain for some days. Once it reaches a fruit, however, it quickly enters.

The first worms to hatch usually enter the fruit at the blossom or calyx end. At this time the apples are very small, and the closed calyx cup offers the best shelter. Later in the season, when the fruit is larger and the rapidly growing apples often touch leaves, twigs or other apples, thus offering good chances for concealment, many of the larvae enter the fruit through the side. When fruit has been scarred by mechanical injury, the attack of insects or by sprays, the roughened surface also offers good opportunity for the young larvae with their small jaws to bite through the skin.

Experiments with larvae fed upon foliage alone, showed that very often they can survive for a week or ten days, and in some instances for fifteen to twenty-one days. It was found, however, that these larvae made very slow growth and there is little likelihood, therefore, that the insect could carry through to the pupal stage in the absence of fruit.

After feeding for about three weeks, the larvae become full-grown and eat their way out through the side of the fruit. These mature larvae measure about three-fourths of an inch in length and are white or pinkish-white in color. This stage of the insect is the one most often seen and most familiar to the fruit growers. Upon leaving the fruit, the larvae immediately crawl away in search of a suitable hiding place in which to spin their cocoons.

Cocoon. (See Plate I.). The cocoons of the overwintering larvae are very tough, being formed of closely woven silk threads with bits of bark or trash attached to give added protection. In the spring, when ready to pupate, the larva usually remodels the cocoon, lengthening it somewhat, or forming a tube-like passageway to the outside of its hiding place to aid in the escape of the moth. The summer cocoons are much lighter, more loosely woven, and somewhat longer than those in which the larvae winter over. Occasionally cocoons are spun in wormy apples and in the soil near the base of the tree.

Pupa. (Plate I.). The pupa is formed within the cocoon and is about one-half inch in length. It is at first light brown in color, but rapidly darkens. When transformation is completed and the moth is ready to emerge, the pupa wriggles out through the end of the cocoon, protruding far enough to allow the moth to escape.

Seasonal History

Overwintering Larvae

The insect passes the winter as a full-grown larva within a tightly-woven cocoon. In the orchard these are found beneath rough bark and in crevices or pruning scars on the trees. The larvae also find shelter in old boxes, in and around packing sheds; in fact, almost anywhere where fruit is gathered and stored at time of harvest.

The overwintering larvae comprise those first brood larvae which did not transform to moths the same season, and all of the second brood larvae which developed in late summer or early fall. The majority of the first brood larvae spin their cocoons in the orchard, while many of the second brood larvae are harvested with the fruit and constitute the greater part of the "worms" which spend the winter in packing sheds and storage houses.

Spring Brood.

Pupation. The first step in seasonal development is the pupation of these overwintering larvae. This begins about the time the fruit buds of the apple first show pink, usually the last of April or early in May, and may continue for six to eight weeks.

The time when a larva matures, or the brood to which it belongs, does not appear to determine the time of its pupation. Second brood larvae, maturing in September or October, often pupate as early in the following spring as do first brood larvae which left the fruit in June. Larvae of the same brood and age often pupate from two to eight weeks apart. The last few stragglers to pupate, however, were always second brood larvae.

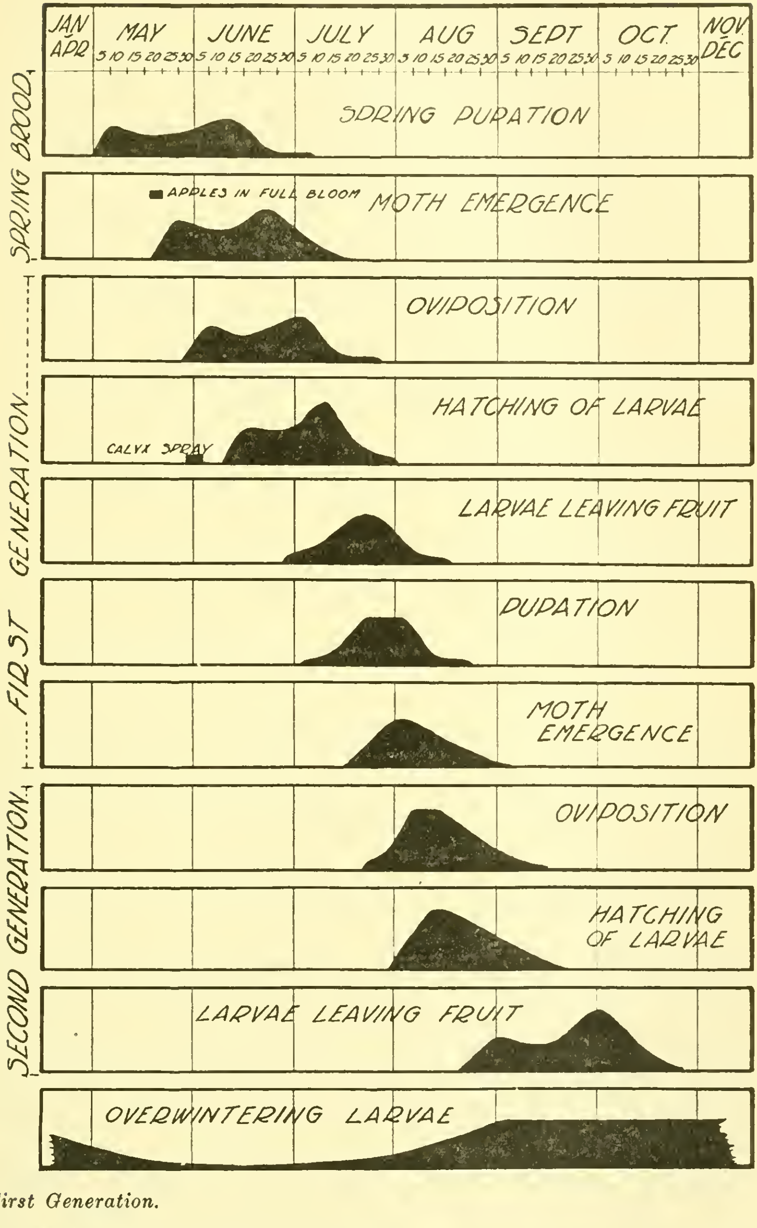
The time spent in the pupal stage, in the seasons covered by our studies, averaged twenty-two to twenty-four days for those larvae transforming before the middle of May. The period gradually shortened as the season advanced and warmer weather approached. In late May and early June the insects spent ten to twelve days in the pupal stage before transforming to moths.

Moth Emergence. Depending somewhat on the season, moths begin to appear the middle to last of May, at which time, or shortly after, apples are in full bloom. The period of moth emergence is shorter than that of pupation since the time spent as pupae decreases as the season advances. Most of the moths appear within five to six weeks, with a few stragglers emerging in the following week or ten days.

In Massachusetts, there has been a tendency for moths to emerge in large numbers at two rather widely separated periods. The first of these falls with regularity close upon the time of the "calyx" or petal fall spray. Following this is a period of rather slight emergence for two to three weeks, with a sharp rise to a second peak of great emergence usually three to four weeks after the first. Around this second peak is usually the greater part of the total emergence, a fact which makes it desirable to know each year when it occurs, so that cover sprays may be accurately timed.

This concentration of moth emergence into two rather widely-separated peaks appears to be due chiefly to weather conditions. In Massachusetts, the transition from winter to spring is usually marked by warm and favorable weather which hastens all seasonal development. There usually follows a period of cold, inclement weather which continues sometimes well into June, when development is slowed up until the approach of more uniformly warm weather. The insect in all stages is very sensitive to climatic conditions. This explains why in 1925, when a period of very high temperature was encountered early in June, seasonal development was speeded up very noticeably and the second peak of moth emergence occurred but two to three weeks after the first.

Figure 1. Seasonal History of the Codling Moth, Amherst, Mass., 1924.



First Generation.

Oviposition. The period from emergence of the moths until the females begin laying eggs varies considerably. If the weather is cold, a week may elapse between these two events. The first moths to emerge in the spring usually deposit eggs in from five to seven days. In late May and early June, oviposition begins in from two to four days.

Egg laying usually begins the third to fourth week of May, and may last until late July. Oviposition corresponds very closely with the emergence of moths, and is very irregular since it is governed by the temperature at dusk or in early evening when most of the eggs are deposited. If the temperature is 60° F. or less at this time, the moths show little activity and very few eggs are laid. A sudden drop in temperature, or showers in late afternoon, decreases the number of eggs laid that day. Prolonged cold and unfavorable weather during the egg laying period greatly influences both the time and amount of the season's oviposition.

Hatching. In hatching, the young larvae break through the upper surface of the egg shell, usually close to the margin. They have never been found to emerge through the under surface even when eggs are laid on the fruit. The larvae, therefore, do not bore directly into the fruit without crawling somewhat over the surface.

The incubation period of the eggs varies from four to twelve days, but most of them require six to seven days. The wide variation is due to the fact that, in this stage, the codling moth is particularly sensitive to climatic conditions and responds very quickly to any sudden rise or fall in temperature. The close correlation can be seen from the following record obtained in our studies in 1923.

Daily maximum temperature	Eggs hatched in
56°—65° F.	9—10 days
73°—80° F.	7— 8 "
85°—94° F.	6— 7 "
87°—89° F.	6 "
92°—97° F.	5 "

Larval Development. The young larvae, or "worms" may be expected to appear in about two weeks after the emergence of the moths. Their appearance marks the period when infestation of the fruit takes place. When it is recalled that moths are emerging over a period of six weeks or more, it is easy to see the necessity for timely sprays to protect the rapidly growing fruit from infestation.

The length of time spent by the "worms" inside the fruit has been found to be very uniform year after year. Protected as they are within the fruit, they are not greatly affected by outside conditions. On the average twenty-one to twenty-three days elapse from the time the newly-hatched "worms" enter the fruit until they emerge as full-grown larvae.

The period during which they mature and are leaving the fruit varies considerably according to the season. In a typical year, mature larvae are found about the first week of July. In 1925, an early season, they were leaving the fruit by the 25th of June; in 1926 a backward season, none were found until July 20.

Among those larvae which transform in the summer, there is much irregularity in the time elapsing between their emergence from fruit and pupation. Such wide variation is hard to explain. It appears to be an individual matter. A few pupate at once upon leaving the fruit. Most of them transform within six to nine days. A number, however, were found to have delayed for seventeen, nineteen, twenty-eight, and, in one ease, thirty-one days before pupating. Larvae of the same age often pupated one to two weeks apart.

Pupation. In a normal season, pupation usually commences the second week of July and continues for a month or six weeks. The greater part of it, however, takes place during the third or fourth weeks of July. The pupal stage lasts on the average ten to twelve days. If the weather is very warm, moths may emerge in six to eight days. In a few cases, fifteen to sixteen days are passed in this stage, and one record was taken in which twenty-six days elapsed before the moth emerged. There is, however, no such irregularity, at this time, in the duration of the pupal stage as has been noted in the studies of spring pupation. This is due very largely to the more stable and uniform weather conditions prevailing during midsummer.

Transforming and Overwintering Larvae. The relative number of first brood larvae which transform the same season to moths and those which overwinter, is determined very largely by the time they mature and emerge from the fruit. This association of date of maturity and degree of pupation can be seen from the following record taken from our life history studies.

Date larvae emerged from fruit	Per cent pupating
Last of June to first week of July	Approximately 100 per cent.
First week ot July to third week of July	Approximately 75 " "
Third week of July to first week of Aug.	Approximately 25 " "
After first week of August	Less than 5 " "

This explains why in an "early" season such as 1925, when a large number of larvae matured in late June and early July, there followed an unusually large second brood. Conversely in 1926, a "late" season, mature larvae were found to be leaving the fruit late in July, and the second brood proved to be almost negligible.

Moth Emergence. Emergence at this season is more uniform than in the spring, and there has not been any indication of a second peak of maximum emergence. The first moths usually appear the third or fourth week of July and continue to emerge for the next four or five weeks. They are emerging in greatest numbers during the last week of July and the first ten days of August. This is fairly constant year after year, however "early" or "late" the season has been up to that time.

Second Generation.

Eggs. These moths begin to deposit eggs within two to four days after emergence. As in the spring, the eggs are laid singly upon foliage, twigs, and fruit, but a much larger percentage of them are deposited directly on the surface of the fruit than is the case in the first brood.

The time required for them to hatch averages from five to six days, but there is a slight tendency for this period to lengthen toward the latter part of August and early September when somewhat cooler weather prevails.

Since young larvae appear in seven to ten days after the first moths emerge, the greater part of this brood of "worms" appears from August 10 to 20. Stragglers are found, however, until well into September.

Larvae. Upon hatching, the young "worms" lose little time in reaching the fruit and burrowing into it. Very many of this brood enter through the side of the apple, usually where it touches a leaf, twig, or other apple.

Second brood larvae, as a rule, remain in the fruit longer than do those in the spring, especially in late September and in October. Life history studies showed that the average time spent in fruit was as follows:

Date of Maturing	Time spent in Fruit
During August,	20—22 days
During September,	28—30 days
During October,	35—40 days

These larvae are maturing and leaving the fruit in largest numbers from the first of September to early October. After emerging, the larvae at once form their closely woven winter cocoons in any convenient place offering concealment and protection. Within these cocoons, they pass through the winter, transforming to moths the following spring. In Massachusetts, the insect has shown no tendency toward any pupation in the fall or toward a third brood of moths.

Overlapping of Broods.

A study of the seasonal history of the codling moth shows that in a typical season there is an overlap of three to five days between the last emerging spring moths and the first of the summer brood. By the time the last of the spring moths had died, the greater part of the summer brood had emerged. It is evident, therefore, that moths may be present in an orchard continuously from late May until the middle of September.

The different life stages are so prolonged that the first larvae to hatch in the spring pupate before egg deposition is finished. Larvae are hatching for three weeks or more after pupation has begun. There was found to be a gap of seldom more than two or three days between the time egg laying by the spring moths had ceased and the first eggs of the summer moths are laid, and sometimes they overlap.

It is evident, therefore, that every year some stages, at least, of the two broods overlap, and consequently there are few days during the season, after the fruit has set until harvest, when it is not subject to infestation.

Below is shown a comparison of some of the more important stages in the development of the insect with the seasonal development of the apple, for the three-year period studied:

Apple Development	**Insect Development**
Blossom buds showing pink	Beginning of pupation
1—6 days before ''calyx'' spray	1st moths appearing
''Calyx'' spray	1st period of maximum appearance of moths
3—4 weeks later (2—3 weeks in 1925)	2d period of maximum appearance of moths

Some of the more important events in the seasonal history of the codling moth, from the three seasons' study in Massachusetts, are summarized in the following table:

	1923	1924	1925
Beginning of pupation	May 3	May 3	April 24
Date of last pupation	June 26	July 11	June 20
Duration of pupa stage	8–24 days	12–23 days	8–24 days
Emergence of 1st moths	May 27	May 24	May 12
1st period of maximum emergence	June 2–4	May 26–30	May 16–18
2d period of maximum emergence	June 20–22	June 22–27	June 3–9
Date of last emergence	July 2	July 24	July 3
Duration of egg stage	5–10 days	4–12 days	4–11 days
Appearance of 1st brood larvae	June 7	June 13	May 29
Emergence of 2d brood moths	July 20–Aug. 20	July 21–Sept. 3	July 11–Aug. 28
Period of greatest emergence	Aug. 3–6	Aug. 4–9	July 31–Aug. 12
Appearance of 2d brood larvae	Aug. 1–Sept. 6	Aug. 2–Sept. 17	July 24–Sept. 12

Control

Natural Enemies.

Two species of tiny hymenopterous parasites,* which live the greater part of their life in the body of the codling moth larvae, have been reared in Massachusetts. Neither of these is sufficiently abundant, however, to be of economic importance. Spiders, ants, and various beetles also destroy many larvae while they are migrating from the fruit, and, in some cases, after they have spun cocoons. The most active enemies of this pest are birds. Woodpeckers and nuthatches collect large numbers of larvae from their wintering cocoons, while other insectivorous species capture many of the "worms" during the summer.

Unfavorable weather conditions also provide a natural check on the increase of this pest. Severe winter weather, particularly sudden changes from moderate to extreme cold, has been observed to kill at least 10 per cent of the wintering larvae, and approximately 2 per cent of them succumb in a normal winter. Cold, damp weather during moth activity greatly decreases the number of eggs laid.

Control Methods Other Than Spraying.

There are several operations other than spraying which reduce the damage caused by the codling moth. They cannot be substituted for careful spraying but are very helpful to any fruit grower who has difficulty in controlling this pest.

Thinning. In thinning, remove and destroy all wormy apples and break clusters so that no fruits will touch each other. This kills many worms and eliminates the protection offered by two adjacent apples which is so desirable to young codling moth larvae when entering the fruit. Destroy the wormy apples rather than leave them on the ground. Feeding to hogs, burning, or burying under at least a foot of packed soil will do this. Picking bags are convenient receptacles for carrying them. Some fruit growers find it profitable to pay a premium for wormy apples at thinning time.

Banding Trees. The habit of codling moth larvae of spinning cocoons under bark and in crevices has led to the use of cloth band traps. In preparing the trees for banding, scrape all loose bark from the trunk and fill cracks and holes. A triangular box scraper or sharpened hoe is good for this work, and if it is done in the winter many hibernating worms will be killed. The bands are preferably made of burlap cut in strips about twelve inches wide and folded once lengthwise, being slightly longer than necessary to extend around the trunk. The bands are placed around the tree at a convenient height below the large branches, and held in place by two finishing nails which are driven into the trunk and forced through the top and bottom of the overlapping ends of the band. To trap the summer brood of worms, put the bands in place July 1 and kill the worms and pupae under them every eight days until September. To trap the overwintering worms only, put the bands in place about August 15 and kill the worms under them anytime during the winter. Experiments show that about one-third of the worms can be destroyed in this way, the number depending on the thoroughness with which the scraping and examining is done. *Do not put bands on your trees unless you kill the worms under them.*

**Ascogaster carpocapsae* (Vier.)
Glypta varipes Cress.

Bait Traps. Codling moths are not attracted to lights as are many insects. They may, however, be attracted to certain odors. Recent experiments in the Northwest have shown an increased control of 12 to 15 per cent where pans of fermented apple juice were hung in trees in a sprayed orchard. Such baits are most effective during the maximum flight of the moths which in Massachusetts occurs from May 15 to September 1. Pans or wide-mouthed pails or jars are used for containers, and the bait must be kept uniform by cleaning out debris and renewing to prevent evaporation and dilution. Baits for the codling moth have not been thoroughly tested in this State and are recommended as an experiment only.

Disposal of Cull Apples and Protection of Storage. Worms in cull apples are often the means by which damaging infestations are carried over from year to year. To avoid this, pick all fruit from the trees and ground, and dispose of it quickly. Storage bins at cider presses often harbor large numbers of worms. The bins should be built with a minimum of cracks and thoroughly cleaned during the winter. Many worms spin winter cocoons in boxes, barrels, and parts of the packing shed. It is important to keep all windows, doors, and other openings in the packing shed and storage house screened or closed during the spring and summer. Boxes and barrels should be stored in a "moth-tight" place. One instance is known where more than 3,600 codling moths were collected during the summer at the windows of a shed containing about 1,000 empty boxes. In addition to increasing the infestation in the orchard, moths emerging from larvae wintering in a shed usually appear later than those in the orchard, and seriously interfere with effective control by spraying.

Spraying.

Materials. Lead arsenate is the most satisfactory insecticide for the control of the codling moth. It is manufactured both as a powder and as a paste. Either one is effective when properly used. The powder is more conveniently handled and cannot freeze or dry out.

Arsenic oxide is the active agent in lead arsenate, and Federal standards require at least 12.5 per cent of this in the paste and 25 per cent in the powder. These requirements are so well guarded, especially in brands which enter interstate commerce, that the fruit grower may be assured that his lead arsenate contains the necessary amount of active poison.

The quantity of lead arsenate to be used for spraying is calculated for the powder form, and, when the paste is used, twice the amount by weight is always necessary to obtain the same quantity of active poison.

To control the codling moth, one and one-half pounds of lead arsenate powder in each 50 gallons of water is recommended. In many parts of the country, one pound in 50 gallons has proved sufficient but because of the presence of other pests, such as the plum curculio and the gypsy moth, a greater amount of poison is considered advisable in this State.

Calcium arsenate, magnesium arsenate, zinc arsenite, and Paris green have been used for codling moth sprays but they are either less effective, more expensive, more injurious, or less available than lead arsenate.

Lead arsenate does not dissolve in water but remains as tiny particles suspended in the liquid. When the spray on the trees collects in large drops, these particles settle to the bottom, and upon drying leave many areas on the fruit and leaves which have no coating of poison. To avoid this, materials are added which spread the poison over the fruit in a thin film. Soap and glue are very effective spreaders, but at present calcium caseinate is the most practical material for this purpose. The use of a spreader enables the operator to cover the fruit more completely and prevents much of the blotching on red fruit which results from overspraying.

Calcium caseinate materially delays the undesirable chemical reaction which may result when lead arsenate and lime-sulfur are combined, and altogether its use is justified. (See discussion of spray injury, p. 71.).

Nicotine sulfate has been tested many times as a spray to kill codling moth eggs and in some cases it improved the control. It is an expensive treatment, however, and is now discarded as uneconomical. In the last two years, weak solutions of lubricating oil emulsions have been used experimentally with some success to kill the eggs and small larvae. Oil sprays are natural spreaders and, when used alone, leave no arsenic residue on the fruit at harvest time. The degree of control which they give, however, and the possibility of injury to the trees and fruit by summer applications of oil have not yet been satisfactorily determined.

Suggestions for Spraying Apples to Control the Codling Moth.

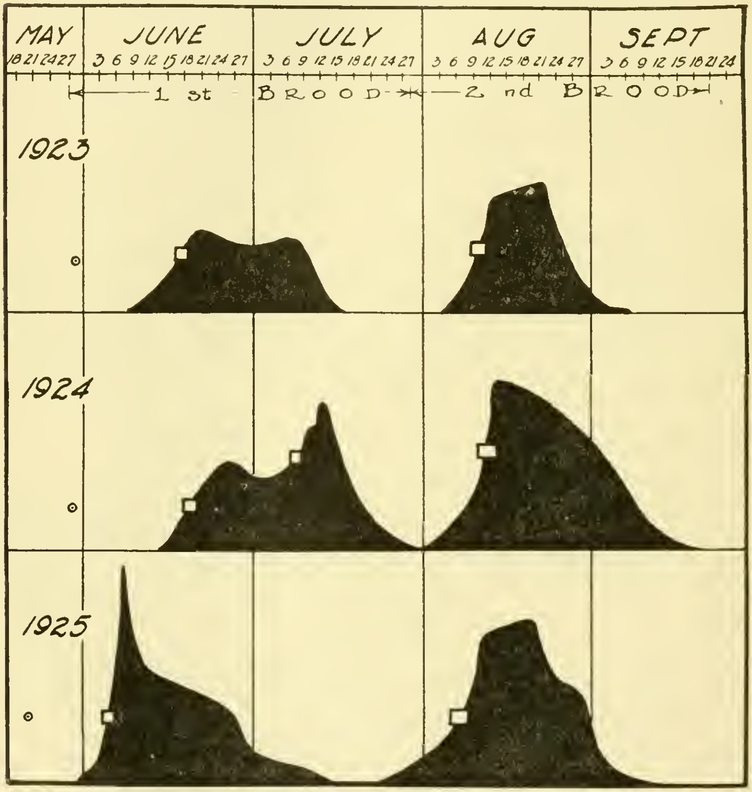
In spraying pay particular attention to the fruit. It must be hit by spray on at least two sides in order to cover it completely. If combating scab, plant lice and other leaf-attacking pests at the same time, the foliage must also be thoroughly covered. Too much spray is sometimes as harmful as too little, and excessive dripping should be avoided. The best coating is applied when a fine misty spray just reaches the fruit. Mist nozzles regulate the type of spray very well but the spray gun must be frequently adjusted by the handle regulator to give the best results (see Plate II), especially when no spreader is used. Do not use spray guns when the wind is blowing. *Thoroughness in spraying is most important.* Every apple should be completely covered regardless of other factors. About five gallons of spray are necessary to cover the average fifteen-year old apple tree, but the amount varies with the size and crop of each tree.

When to Spray Apples to Control the Codling Moth.

Careful timing of sprays is often the key to successful control of the codling moth, and other work should not be allowed to interfere with it. The proper time to apply the calyx spray depends entirely on the development of the tree, while the post-calyx sprays are timed in accordance with the development of the insect. The rate of growth of both trees and insects varies from year to year, and the *exact* date or period to apply post-calyx sprays cannot be accurately predicted in advance. In the following spray schedule the time to spray, as indicated by the detailed studies of the codling moth, is determined approximately for the typical year, with the suggestion that fruit growers secure each season all available information concerning the seasonal development of pests to help them time the sprays more effectively.

In Massachusetts, two sprays, the calyx (No. 3) and a cover, or post-calyx (No. 4), are usually necessary to control the codling moth effectively, while a later spray (No. 7) is advisable in seasons when this pest is unusually abundant.

Figure 2. Dates of Hatching of Codling Moth Larvae, Amherst, Mass.



Small circle indicates approximate time calyx spray was applied.

Small squares show approximate time to apply cover sprays to control codling moth most effectively according to the seasonal history of the insect in 1923, 1924, 1925.

The above dates may not necessarily coincide with those recommended in the spray schedule, which are based on average conditions and are also influenced by other pests.

Calyx Spray. This is the most important spray to combat the codling moth in Massachusetts. It is applied between the time when about 90 per cent of the blossom petals have fallen and the time when the calyx lobes have closed, a period of seven to ten days depending on the weather. Plate II shows the appearance of the fruit during this period. Spraying while the trees are in bloom is unnecessary. For a few days after the petals have fallen, the calyx lobes are laid back in such a way that the cavity containing the stamens and pistils of the flower is open and can be filled with drops of poisoned spray, thus forming a mortal barrier to any worm which attempts to enter the fruit through the calyx cavity at any time during the season. There are no worms attacking the apple when this spray is applied but the calyx cavity offers excellent shelter from wind, sun, and natural enemies while the larvae are entering the apples, and experiments show that 60 to 80 per cent of them take advantage of this protection.

Cover Sprays. The function of cover, or post-calyx, sprays is to place over the surface of the fruit a protective film which will kill codling moth larvae when they attempt to enter through the side. Theoretically these sprays should be applied just before the larvae of each generation hatch and attack the fruit in large numbers, as is shown diagrammatically in Figure 2. In both 1923 and 1924 large numbers of larvae of the first brood hatched approximately twenty days after the calyx spray was applied, while in 1925, due to extremely high temperature, this condition was reached about fourteen days after the calyx spray was applied. In 1924, however, cold weather so effectively delayed development that the greatest number of larvae of that brood hatched about forty-five days after the calyx spray. From this, it is evident that the most effective time to apply cover sprays must be determined each year, but that with average development this period for the first brood larvae will occur about three weeks after the calyx spray. Figure 2 also shows the time of hatching of the second brood larvae in the three seasons when this development was studied. In the well-cared-for Massachusetts orchard, the second brood larvae are usually not abundant; and the latest spray recommended is No. 7, eight weeks after the calyx, in order to combat the apple maggot effectively. This also gives some protection against the attack of second brood codling moth larvae, without the danger of arsenical residue on the fruit at harvest time.

Spray Schedule for the Control of Apple Pests in Massachusetts

The following spray schedule will serve as a basis for spraying apples in Massachusetts. Dusts are not included in this calendar on account of the fact that many experiments indicate superiority of the spray to control a heavy infestation of codling moth. In the average orchard, the first four sprays listed below are advisable. In addition to the four essential sprays, one or more of the special sprays, Nos. 5, 6 and 7, are necessary when the pests indicated are unusually abundant, or abnormal weather conditions make additional protection against them advisable. Fruit growers should secure all the information possible and then use their own judgment as to which of these, if any, they may need to apply.

Spray Schedule For Apples

Prepared by Departments of Botany, Entomology, and Pomology, Massachusetts Agricultural College

Time of Application	Pests	Material	Remarks.
1. **Delayed Dormant** When buds are breaking	San Jose Scale European Red Mite (eggs) Plant Lice	Lubricating oil emulsion, 4 or 5 gals. (3% actual oil) or Commercial oil sprays, according to directions Water to make 100 gals.	This is a very **important** spray for Plant Lice and the only one for Scale and European Red Mite. Always use oil when European Red Mite eggs are present. Do not use oil sprays when there is danger of freezing. Wash all lime-sulfur residue from tank with strong lye (3-5 lbs. per 100 gals. of water) before using oil sprays. Lead arsenate and nicotine sulfate can be mixed with oil sprays, but lime-sulfur can **not**. Use lead arsenate only when Tent Caterpillars are abundant. Slight burning of the buds at this time may follow but is unimportant.
	or		
	San Jose Scale Plant Lice Tent Caterpillar	Calcium caseinate, 1 lb. 40% Nicotine sulfate, ¾ pint Lead arsenate (dry), 3 lbs. Commercial lime-sulfur solution, 12 gals. Water to make 100 gals.	
2. **Pink** Just before blossoms open or earlier if rainy weather threatens. (Usually the buds are pink and have separated in the cluster).	Apple Scab Red Bug Bud Moth Tent Caterpillar Brown-tail Moth Plant Lice Leafhoppers Black Rot	Calcium caseinate, 1 lb. 40% Nicotine sulfate, 1 pint Lead arsenate (dry), 3 lbs. Commercial lime-sulfur solution, 2 gals. Water to make 100 gals.	This is a very important spray for Apple Scab. If no Red Bug is present, reduce the amount of nicotine sulfate to ¾ pint.
3. **Calyx** Within 7-10 days after the petals fall.	Codling Moth Apple Scab Plum Curculio Red Bug Plant Lice Leafhoppers Skeletonizer Gypsy Moth Brooks' Fruit Spot Black Rot	Calcium caseinate, 1 lb. 40% Nicotine sulfate, 1 pint Lead arsenate (dry), 3 lbs. Commercial lime-sulfur solution, 2 gals. Water to make 100 gals.	This is the most important single spray and is essential to effective codling moth control. If no Red Bug is present, reduce the amount of nicotine sulfate to ¾ pint.

Time of Application	Pests		Remarks.
4. **Cover Spray** 3 weeks after calyx spray.	Codling Moth Plum Curculio Gypsy Moth Apple Scab Black Rot Brooks' Fruit Spot Sooty Mold	Calcium caseinate, 1 lb. Lead arsenate, 3 lbs. Commercial lime-sulfur solution, 2 gals. Water to make 100 gals.	This is important for controlling "side" injury by the Codling Moth and late infection by Apple Scab. It is also effective against the Plum Curculio.
		Special Sprays For Apples	
5. **Pre-pink** When the cluster-buds are breaking but before the individual blossom buds separate from each other.	Apple Scab	Calcium caseinate, 1 lb. Commercial lime-sulfur solution, 2 gals. Water to make 100 gals.	This spray is usually necessary to control scab on susceptible varieties like McIntosh and Delicious. When Plant Lice are present, add ¾ pint of 40% nicotine sulfate. If Tent Carterpillars are prevalent, lead arsenate should be added.
6. **Special Plum Curculio** 7-10 days after calyx spray.	Plum Curculio Codling Moth Apple Scab	Calcium caseinate, 1 lb. Lead arsenate, 3 lbs. Commercial lime-sulfur solution, 2 gals. Water to make 100 gals.	This is important where Plum Curculio is abundant. When Scab is not serious or the leaves are well covered from calyx spray, lime-sulfur can be omitted.
7. 8 **weeks after calyx spray**	Apple Maggot Codling Moth Skeletonizer Brooks' Fruit Spot Sooty Mold	Lead arsenate, 3 lbs. Dry-mix sulfur-lime, 25 lbs. Water to make 100 gals.	This spray will kill the Apple Maggot flies before they lay eggs. It is also important in controlling Codling Moth "worms" of second brood. Unless Apple Maggot threatens to be very severe, it is advisable to omit this spray on early varieties, to avoid spray residue at harvest.

Add the materials to the spray tank in the following order after they have been prepared as directed:

1. Water.—Fill tank one-half to two-thirds full before adding materials. Keep agitator running.
2. Calcium caseinate (if used).—Sift into tank or mix each pound in about 1 gallon of water and pour through screen.
3. Nicotine sulfate.—Measure and pour into tank.
4. Lead arsenate.—Wash through screen or mix with a little water and pour through screen.
5. Lime-sulfur.—Measure and pour into tank. If dry form is used, mix with a little water and pour through screen.

THE CHOICE OF FUNGICIDES AS AFFECTING THE CONTROL OF DISEASE AND THE PREVENTION OF SPRAY INJURY

Contributed by W. L. Doran, Department of Botany,
Massachusetts Agricultural Experiment Station

As indicated by the spray calendar, most of the arsenic sprays for codling moth control must also contain fungicides for scab control.

A good fungicide for spraying apples must be one which will control scab and cause no more than a minimum of spray injury when combined with the necessary insecticides. Fungicides which have been used for this purpose are liquid lime-sulfur, dry lime-sulfur, dry-mix sulfur-lime, sulfur dust, and Bordeaux mixture. Liquid lime-sulfur is the cheapest of these. It is dependable for the control of scab. It is used much more generally than any of the others in Massachusetts. However, each has its virtues and weak points with which the orchardist should be familiar.

Bordeaux mixture controls scab but is not at all safe to use on the apple because it so frequently burns or "russets" the fruit.

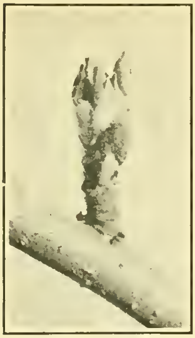
Dry lime-sulfur may be used instead of liquid lime-sulfur, if desired. It has been found to be the equal of liquid lime-sulfur for the control of scab. The ordinary commercial dry lime-sulfur should be used at the rate of 8 pounds in 100 gallons of water. Either liquid or dry lime-sulfur in combination with arsenate of lead may, under some conditions, injure the fruit and leaves of sprayed trees.

Dry-mix sulfur-lime or, as it is often called, Jersey dry-mix (see New Jersey Agr. Exp. Sta. Circ. 177) may be purchased in the commercial form or may be made by the fruit grower. It is made by mixing the ingredients together *dry* in the proportion of 16 pounds fine sulfur, 8 pounds hydrated lime, and 1 pound calcium caseinate. Twenty-five pounds of this mixture is sufficient for one hundred gallons of spray. Dry-mix sulfur-lime is less likely to injure sprayed foliage and fruit than is lime-sulfur, and for this reason it is sometimes substituted, especially for the calyx and later applications. In all except the most severe "scab years," Jersey dry-mix controls scab satisfactorily. In rainy summers, when scab is severe, a somewhat more complete control may be expected from lime-sulfur.

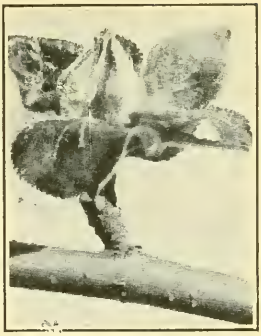
The prevention of spray-injury is almost as important as the control of certain insects and diseases. Spray-injury includes russeting of the fruit and various degrees of burning and curling of the foliage as a result of the application of the insecticide and fungicide. But there are certain other troubles which are sometimes mistaken for spray-injury. Such injury may occur, especially on trees lacking in vigor, regardless of whether or not they are sprayed, if when the leaves are young a period of cloudy or rainy weather is suddenly followed by drying winds and hot sunshine. Under these conditions the edges or tips of the leaves may be burned. The identification of injury to foliage, due to the lime-sulfur-lead arsenate combination spray, is made easier by the fact that the injury, if it occurs at all, is usually apparent two to four days after the applications are made. Spray-injury, especially on the varieties Baldwin and McIntosh, is common following the use of the lime-sulfur-lead arsenate combination, and is most frequently associated with the calyx and post-calyx applications.

Plate II.

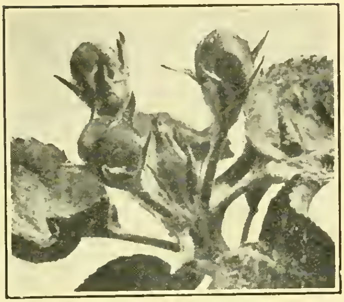
Illustrations Showing Proper Bud Development for Spraying.



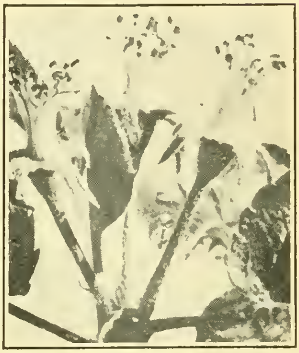
Delayed Dormant



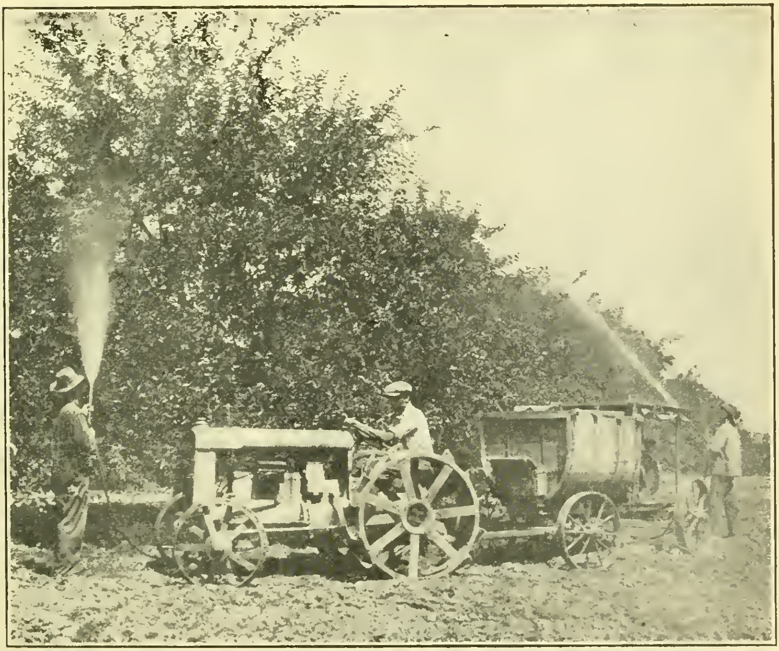
Pre-pink



Pink



Calyx



A good Power Spraying Outfit

Note that the guns are adjusted for two types of spray—the right hand one to reach top of tree, the left for closer work.

Based on work done by the Massachusetts Agricultural Experiment Station and numerous other experiment stations, a brief summary of the knowledge of the prevention of spray-injury is here presented. If these several factors are observed in practice, spray-injury can be reduced in severity.

If, by well-timed early applications, the leaves can be kept relatively free from scab, there will be less spray injury than is likely to occur on leaves which are scabby when sprayed.

A fine mist of spray, with no more than the minimum amount necessary to wet the leaves applied, and that applied without unnecessary violence, are conditions least likely to result in spray-injury.

The safest time to spray with the lime-sulfur-lead arsenate combination is on a cool day when the air is dry and before a rain. The conditions most likely to result in injury occur on a hot day when the humidity is also high and immediately following a rain.

Either dry-mix sulfur-lime or sulfur dust is less likely to burn than is lime-sulfur.

The soluble arsenic, which is one of the causes of spray-injury in the lime-sulfur-lead arsenate combination, is kept low in amount, making the spray safer, if calcium caseinate is used. In filling the spray tank, the calcium caseinate should be put in before either the lime-sulfur or the lead arsenate, rather than to have the two latter meet and react in the absence of the caseinate. The fact that the residue in the spray tank is rich in soluble and dangerous arsenic, makes it important that there be good agitation and that the spray tank be cleaned frequently.

Summary

The codling moth is one of the most destructive insect pests of the apple, and is present practically everywhere this fruit is grown.

The apple is the favored food of this insect and all varieties are attacked. Pears, peaches, cherries, plums, quinces, and walnuts are also infested.

The injury to the fruit is caused by the larvae, or "worms", tunnelling through it and also causing undesirable scars called "stings".

The inconspicuous gray moths lay from twenty to forty small pearly-white eggs during the two or three weeks of their life. The eggs are laid singly on the leaves, twigs or fruit.

Newly-hatched larvae quickly enter the fruit, where they feed for about three weeks. The majority of the first "worms" enter through the calyx end of the apple while later in the season many enter through the side. Young larvae sometimes feed more or less upon foliage before entering the fruit.

In Massachusetts, the codling moth has one complete generation and a partial second, annually.

The winter is passed as full-grown larvae within tightly woven cocoons. These overwintering larvae include a part of the first brood "worms" and all of the second.

Pupation begins the last of April or early in May, about the time fruit buds of the apple show pink.

Moths appear by the middle or last of May, and emergence continues for five or six weeks. Four or five days after they emerge, the females begin to lay eggs although, if the weather is cold or stormy, they may delay longer before ovipositing.

The incubation period of the eggs varies from four to twelve days, with six to seven as the average, so that young larvae begin to appear about two weeks after the emergence of the moths.

Most of the larvae that mature before July 15 transform to moths the same season. Therefore, the relative number of larvae leaving the fruit before that time, in any year, determines the size and importance of the second generation that season.

The greater part of the summer brood moths emerge during the last week of July and first ten days of August, and most of the larvae, or "worms", of this brood appear from the 10th to the 20th of August. These larvae remain in the fruit for three to six weeks, emerging in largest numbers during September and early October.

In Massachusetts, there has been found to be a slight overlapping of the two generations, so that from the time fruit is set until harvest there are but few days when infestation may not take place.

Insectivorous birds, predaceous and parasitic insects, and unfavorable weather conditions provide a natural check to the increase of this pest, but they cannot be depended on to give satisfactory control.

Preventive measures such as careful thinning, banding of trees, the use of bait traps, disposal of culls, and protection of storage houses are valuable as supplementing spraying.

Spraying, on the whole, has proven more effective than dusting. It is the most important phase of codling moth control and should be thorough and timely.

The most important sprays in the control of this insect are the calyx (No. 3 in the schedule) and the post-calyx sprays (Nos. 4 and 7 in the schedule).

PUBLICATION OF THIS DOCUMENT APPROVED BY THE COMMISSION ON
ADMINISTRATION AND FINANCE.

6,000. 3-'27. Order 8311.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 234 MARCH, 1927

THE POISONING OF HONEY BEES BY ORCHARD SPRAYS

By A. I. Bourne

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For many years the question of possible injury to honey bees from the use of poison sprays upon fruit trees has been the subject of discussion and controversy. Recent studies made by the Experiment Station indicate that there is little danger of killing honey bees by spraying orchards, even when some bloom is present, if the recommended combination of lead arsenate, lime-sulfur and nicotine sulfate is used. This bulletin contains the record of these studies, carried out both in the laboratory and in the orchard.

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AGRICULTURAL EXPERIMENT STATION,
AMHERST, MASS.

THE POISONING OF HONEY BEES BY ORCHARD SPRAYS

By A. I. Bourne

The importance of honey bees in the pollination of blossoms, thus insuring the set and yield of fruit, has long been recognized by orchardists, many of whom own colonies of their own or rent them from neighboring beekeepers during the blossoming period. The question, therefore, "Does spraying orchards kill bees?" has been one of vital interest to both fruit growers and beekeepers ever since the use of poison sprays to combat orchard pests has become general. It has been the subject of a great deal of discussion and, undoubtedly, led to considerable ill feeling, yet comparatively little has been done in the way of actual experiments.

Years ago, before insecticides or methods of using them had become standardized or any well defined spray schedule developed, growers attempting to control their numerous pests undoubtedly did much spraying which was ill timed and dangerous to bees. An investigation was begun by the Station in 1922 to determine whether present day practices, using the common spray combinations according to the schedule now recommended, would cause any serious mortality to bees. The work was carried out in coöperation with Professor N. E. Phillips and, later, Professor M. H. Cassidy who had in charge the care and manipulation of the colonies and who made the observations on the behavior of the bees during the experiment.

Laboratory Experiments.

Behavior of bees fed on the common spray mixture.

Preliminary studies were made in the laboratory to determine whether bees were attracted or repelled by the combined spray of lead arsenate, lime-sulfur and nicotine sulfate; whether this combination if fed upon by bees would prove fatal; and what the symptoms of poisoning were.

A single frame nucleus, without stores, in an observation hive was fed a mixture of honey and the three insecticides diluted as for orchard spraying, and the reaction of the bees was noted. The temperature during the experiment was kept about 60°F., a temperature at which bees feed readily, yet do not become too active within the confined space.

For several days after being transferred, the bees were fed a dilute honey solution, which they readily accepted. During this period the number of bees that died each day was recorded, to determine the normal daily mortality. The bees were then offered a mixture of equal parts of honey and the spray combination. They were very strongly repelled by this mixture and only one or two were observed to feed upon it at all. The bees even showed a strong tendency to move away from that part of the comb near the feeder. The few bees which had taken some of the mixture were taken out of the hive and isolated to note their reaction. All of them showed symptoms of poisoning and died within twenty-four hours.

The spray mixture without nicotine sulfate proved slightly distasteful to the bees. When both lime-sulfur and nicotine sulfate were left out of the spray and lead arsenate alone was offered the bees, they showed no reluctance toward feeding, but clustered about the feeder in large numbers and consumed a liberal amount of the liquid.

Within twelve hours after the first liberal feeding, bees began to die in large numbers. The peak of mortality occurred within forty-eight hours, and the colony was completely exterminated in nine to ten days. Except when fed the poison mixture, the bees were kept supplied with dilute honey during the run of the experiment.

The record of daily mortality during the experiment is as follows:

Date	Dead Bees	Date	Dead Bees
Dec. 30	1	Jan. 7	140
31	2	8	220
Jan. 1	2	9	85
2	1	10	99
3*	7	11	52
4**	17	12	31
5***	199	13	7
6	318	14	2
		Total	1183

* Date when honey-spray combination was offered.
** Date when lead arsenate-honey mixture was offered (¼ oz.).
*** Date when lead arsenate-honey mixture was offered (⅛ oz.).

From the above it can be noted that in forty-eight hours after the first feeding of the lead arsenate-honey mixture, approximately 50 per cent of the colony was dead. The extended period of high mortality indicates that some of the bees evidently fed upon the poison very sparingly or not at all. During the latter part of the experiment, the normal mortality would be expected to be somewhat higher, due to the long period of confinement.

Relative toxicity of the different materials.

To determine how toxic each material of the combined sprays was to the bees, nine lots of bees were confined in cages and offered a mixture of honey, and the different insecticides used alone and in combination. One lot was given water alone to serve as a check, and another dilute honey to show normal length of life.

Bees naturally fed at once on the water and dilute honey mixture. Lead arsenate did not appear to be at all repellant to them. When it was combined with lime-sulfur, bees fed readily on it. The combination of all three materials, however, appeared to be very repellent, and the bees did not begin to feed upon it until after two or three hours. The mixture of lime-sulfur and honey was taken quite readily; of lime-sulfur and nicotine sulfate was not touched for several hours; while that of nicotine sulfate and honey was very repellent to the bees. They showed a marked aversion toward all combinations containing nicotine sulfate, and for a long time would not feed upon them at all, and even then only sparingly.

The materials used, dilutions, and reactions of the bees were as follows:

Food	All Bees Dead	Reaction of Bees
1. Water	94 hours	Quiet; peak of mortality in 30 hours.
2. Water, 1 part Honey, 1 part	517 hours	Fed in normal manner.
3. Lead arsenate 1½-50, 1 part Honey, 1 part	70 hours	Peak of mortality in 15 hours. Bees fed readily and showed typical symptoms of arsenical poisoning.
4. Lead arsenate 1½-50 } Lime-sulfur 1-40 } 1 part Honey, 1 part	73 hours	Peak of mortality in 20 hours. Bees fed freely.
5. Lead arsenate 1½-50 } Black-leaf "40" 1-1000 } 1 part Honey, 1 part	24 hours	Bees repelled at first, but soon fed.
6. Lead arsenate 1½-50 } Lime-sulfur 1-40 } 1 part Black-leaf "40" 1-1000 } Honey, 1 part	27 hours	Bees fed after 2 hours.
7. Lime-sulfur 1-40 } Black-leaf "40" 1-1000 } 1 part Honey, 1 part	235 hours	Bees fed after 2 hours, but fed sparingly.
8. Lime-sulfur 1-40, 1 part Honey, 1 part	271 hours	Bees fed very soon. Peak of mortality in 24 hours.
9. Black-leaf "40" 1-1000, 1 part Honey, 1 part	370 hours	Bees distinctly repelled. Fed barely enough to maintain life.

The toxicity of the different materials varied greatly. Lead arsenate alone and in all its combinations was very toxic. Lime-sulfur alone or combined with nicotine sulfate was far less toxic. Nicotine sulfate alone was the slowest of all the materials to kill. This was due to the fact that it was so repellent to the bees that they fed but slightly upon it, and that the nicotine probably volatilized so that much of the toxic principle was dissipated.

It is significant that lead arsenate in certain combinations was much faster in its killing action that when used alone. The mixture of all three materials, which is the regular combination recommended for spraying, proved to be one of the most toxic of all.

Symptoms of poisoning.

Bees poisoned by the combined spray soon became sluggish and, although able to vibrate their wings slightly, appeared soon to have lost the power of flight. They began to stagger about, twisting and tossing their abdomen. Attempts to crawl soon became more and more feeble, the legs appearing to be paralyzed and unable to support the body. There were occasional periods of violent tossing and spinning about, becoming gradually shorter and more infrequent. In the last stages, the bees became practically motionless except for occasional feeble and spasmodic vibration of legs and antennae. They usually died with abdomen much distended and tongue protruded.

When the bees were poisoned by lead arsenate alone, the symptoms were practically the same as above except the twisting and tossing about were more violent.

When the bees were killed by lime-sulfur, somewhat different symptoms were noted. The actions of the bees were less violent, and they showed a tendency to be inactive and sluggish.

Bees poisoned by nicotine-sulfate reacted in much the same manner as noted following a contact application of nicotine spray. There was very little violent action. The bees quickly lost control of their limbs and became incapable of any motion except to feebly move legs or antennae.

Mortality in a nucleus colony under controlled conditions.

Feeding tests had shown that, while the combination of lead arsenate, lime-sulfur, and nicotine sulfate at strengths used for orchard spraying was distinctly repellent to the bees, it proved to be very toxic even when taken in small amounts, and its killing action was very rapid. To determine the reaction of bees toward blossoms sprayed with the combination, a three-frame nucleus with eggs, brood, and some stores was placed in a section of tightly screened greenhouse. A thin coating of whitewash on the glass diffused the sunlight somewhat and also reduced abnormal activity of the bees. The colony was kept well supplied with fresh blossoms and allowed several days to become accustomed to the surroundings, and the normal daily mortality determined.

Bloom sprayed with the regular combination was then introduced and allowed to remain for two days. It was then withdrawn and fresh unsprayed blossoms supplied the bees during the rest of the experiment. The following indicates the daily mortality.

Date	Dead Bees	Date	Dead Bees
May 4	18	May 15	406
5	7	16	202
6	36	17	232
7	17	18	108
8	63	19	115
9	51	20	125
10	39	21	120
11	40	22	120
12*	120	23	128
13*	170	24	120
14	313	25	112
		Total	2662

* Days sprayed blossoms were offered the bees.

The bees were strongly repelled by the spray and would not even alight on the blossoms until it had dried. During the next day and until the sprayed blossoms were withdrawn, the bees were visiting them in numbers, although they never worked them as freely as they did unsprayed bloom. The rapid rise in mortality following exposure to the sprayed flowers indicated that bees, although apparently reluctant to work sprayed bloom, nevertheless would do so if no unsprayed blossoms were available. It also pointed out how toxic the spray is to bees, once they feed upon it. Upon the sprayed blossoms the bees naturally obtain the poison greatly diluted. and consequently the toxic effects were noted over a longer period than in the feeding tests above.

Orchard Experiments.

In Massachusetts, apples are the main orchard crop. Since bees do not visit the orchards to any extent except when the trees are in bloom, the two sprays involved are the pink and the calyx. The pink is scheduled to be applied just before the blossoms open, and the calyx when about 90 per cent of the blossom petals have fallen and before the calyx cups close. The fruit grower sprays when most of the trees are in the proper condition. The period allowed for these sprays, however, is limited. If unfavorable weather is encountered, the pink may not be completed before some of the blossom buds have opened. In a mixed planting, certain varieties come into bloom later than others. There is also considerable variation in the bud development in a single tree. This means, therefore, that for the calyx spray especially, the grower must often spray when some blossoms are open. The following experiments were conducted to determine what effect these sprays have upon bees.

Effect of a late pink application.

A normal ten-frame colony was placed in the center of an orchard several days before the trees were to be sprayed. A sheet was spread in front of the hive to facilitate observations on the behavior of the bees, if any should show symptoms of poisoning.

When the center bud of the blossom clusters had opened and the other buds were just separating, the bees were confined and the trees thoroughly sprayed with the combination of lead arsenate, 1½ lbs. to 50 gallons; lime-sulfur, 1:40; and nicotine sulfate, 1:1000. The bees were then released and their reaction noted.

Several hours after the spray was applied, a few bees were observed visiting the blossoms. During the next two days, the bees showed slightly greater willingness to work upon sprayed bloom, but never did so in large numbers. The trees soon came into full bloom and the bees began working the blossoms normally.

During the five days following the spray, including one stormy day when the bees were inactive, less than fifty dead bees were collected on the sheet in front of the hive. A few bees collected from sprayed blossoms and placed in cages for observation, in a short time showed typical symptoms of poisoning and died within twenty-four hours. So far, however, from becoming disabled by exposure to sprayed bloom, the colony within a week was found to be upon the point of swarming.

The experiment demonstrated that bees which actually worked the sprayed blossoms were poisoned. The trees opened into full bloom so quickly after the time the spray was applied, however, that the bees had ample opportunity to work bloom containing no poison, so that the loss to the colony was negligible.

Effect of an early calyx spray.

A colony similar to that used in the previous experiment was placed in a block of twenty-one apple trees in bloom, which the bees worked freely. A sheet was spread in front of the hive, as before, and the bees were confined while the spray was applied. The same materials and dilutions were applied as a spray just after the height of bloom had been reached.

Scarcely any bees worked the bloom during the remainder of the day after spraying, and very few the following day. During the next two days some bees were observed working the bloom but not as freely as before the trees were sprayed. Heavy rains and high wind followed, which prevented activity of the bees, and when favorable weather returned there was little bloom left to attract the bees to the trees.

The colony was kept under observation for ten to twelve days after the spray was applied, to note any marked increase in mortality. During this period less than one hundred dead bees were collected. The greatest number found in any one day was fifteen. Some of the bees collected from the sheet before the hive entrance showed characteristic symptoms of spray poisoning. Frequent examination of the colony during the experiment and at its close showed it to be healthy and in normal condition.

In this experiment, as in the preceding, there was evidence of a marked repellent action of the spray on the bees for at least one or two days, and at no time after the spray was applied did the bees visit the blossoms in such numbers as before. Some few bees showed symptoms of spray poisoning, indicating they had worked the sprayed blossoms. The mortality was so insignificant, however, as to make it evident that most of the bees availed themselves of the abundant unsprayed bloom in nearby orchards.

Experiments with trees enclosed in tenting.

The colonies in the orchard experiments above had in each case failed to show any serious effects from exposure to sprayed bloom. The combined spray, while unattractive to the bees, had been found to be very toxic to them, even when taken in small amounts. It was possible, therefore, that many of the bees had died or become disabled before they could return to the hive. Examination had shown but few bees dead or dying beneath sprayed trees. In an orchard in grass, however, it was almost impossible to make an accurate collection.

It has been observed by beekeepers that bees forage over a radius of at least two miles from the hive in search of nectar and pollen. It was possible, therefore, that the bees in the experiment traveled to other orchards near by and also that other bees were visiting our sprayed trees. The College Apiary and one or two private beekeepers were located within this area of possible danger.

To determine with greater accuracy the mortality of the bees and also prevent possible damage to neighboring colonies, the experiment was conducted during 1925 using trees enclosed within tenting.

Four twelve-year-old peach trees were covered with two thicknesses of tobacco tenting, enclosing an area approximately forty feet square. Cloth was spread on the ground within the tent to facilitate collection of dead bees. A colony of bees was placed within this area and allowed several days to become accustomed to their surroundings.

When considerable bloom had opened, the trees were sprayed with the combined mixture. Several days later, when the bloom was at its height, another application was made in order to cover the newly-opened blossoms. In one spray, lead arsenate alone was used. When peach bloom had passed, masses of apple blossoms were supplied the bees.

The daily mortality, the mean hourly temperature during the part of the day bees were active, the weather conditions and the activity of the bees during the experiment were as follows:

Date	No. Dead Bees	Mean Hourly Temp. ° Fahr.	Weather and Activity of Bees	Remarks
April				
30	3	42°	Cloudy (rain); little activity	
May				
1	16	50°	Cloudy; little activity	Blossoms opening
2	20	52°	Clear; active	
3	109	57°	Clear; active	
4	110	61°	Cloudy; fairly active	Combined spray
5	127	58°	Cloudy, inactive	
6	94	54°	Cloudy (little clear); inactive	
7	65	54°	Cloudy; almost no bees active	Bloom at height Combined spray
8	46	51°	Cloudy; almost no bees active	
9	107	55°	Cloudy; almost no bees active	
10	115	63°	Clear; bees fairly active	Blossom petals dropping
11	......	60°	Cloudy, rain all day; no bees active	
12	118	60°	Clear; bees active	
13	156	65°	Clear; bees active	Bloom about all gone
14	94	67°	Clear; bees active	
15	81	56°	Cloudy, rain; very little activity	Apple blossoms introduced
16	129	65°	Cloudy; very little activity	Lead arsenate alone
17	129	70°	Clear, later cloudy; very little activity	Fresh blossoms introduced
18	186	61°	Clear, cool wind; some bees out and active	
19	177	64°	Clear, cool wind; few bees out and active	
20	30	71°	Clear; bees fairly active	Bloom about all gone
21	29	70°	Clear; bees fairly active	

Considerable unevenness was noted in the opening of blossoms, so that throughout the experiment there were always many blossoms not covered by the spray.

Before the sprays were applied, bees worked the blossoms freely. They were very strongly repelled by the spray, however, particularly before it had dried. Several hours after the trees were sprayed, a few bees were observed to be visiting the trees.

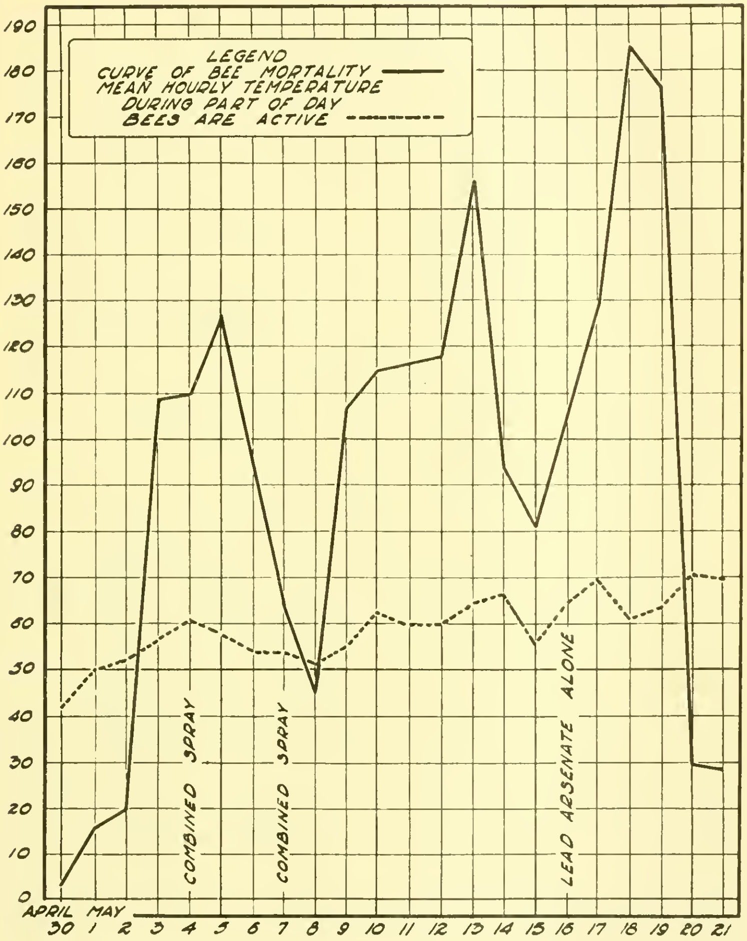
Unfavorable weather conditions during the period of the experiment allowed but brief and infrequent activity of the bees, so that only slight correlation was shown between the time of spraying and the mortality of the bees (Fig. 1). The only mortality which could be given any significance followed the application of lead arsenate alone. Even then, the number of bees killed was comparatively small.

The following season (1926) the experiment was repeated. A normal ten-frame colony was introduced into the tent on May 3. The bees were allowed several days in which to become accustomed to their surroundings before the daily record of mortality was made. This was possible because of the fact that the colony was introduced a number of days before the blossom buds began to open.

Weather conditions were on the whole more favorable for bee activity than was the case in 1925. In both seasons, however, there was considerable unevenness in the opening of bloom, which furnished a continuous supply of newly-opened blossoms, so that after each spray bees had fresh unsprayed bloom available.

At the close of the blooming period of the peach, apple bloom was plentiful. The experiment was extended to cover a good part of the period of apple bloom, which allowed two extra applications of spray. The supply

Figure 1. Daily Mortality of Honey Bees in Relation to Experimental Sprays, 1925.



of apple bloom was replenished often enough to insure fresh blossoms upon which the bees would work. The combined spray was applied May 15 and 26, and arsenate of lead alone on May 17 and 22. The heavy rain following the first combined spray washed off most of the spray so that a new application was made the 17th.

The record of daily mortality, mean hourly temperature during part of day bees were active, weather conditions and activity of bees follows;

Date	No. Dead Bees	Mean Hourly Temp. ° Fahr.	Weather and Activity of Bees	Remarks
May				
5	163	56°	Fair, warm; active	A few buds showing pink tips
6	125	65°	Cool wind; slight activity	
7	......	67°	Cool wind; very slight activity	
8	84	60°	Cool wind, cloudy; very slight activity	
9	100	50°	Cool wind, cloudy; slight activity	
10	66	55°	Cool wind, cloudy; very slight activity	
11	92	54°	Cool wind, cloudy, some rain; very slight activity	
12	126	59°	Fair, cool; slight activity	
13	237	68°	Fair, warm; very active	Blossoms opening
14	......	58°	Cloudy, rain; very slight activity	
15	114	57°	Windy, warm; active	Combined spray
16	123	56°	Rain; slight activity	
17	78	65°	Warmer, cloudy; very slight activity	Lead arsenate alone Bloom all out or nearly so
18	325	73°	Clear, warm; active	
19	175	67°	Windy, warm; active	
20	100	55°	Fair, cooler; active	Petals beginning to fall
21	64	64°	Fair, warm late in day; slight activity	
22	150	69°	Fair, warm; active	Peach bloom over Apple blossoms introduced Lead arsenate alone
23	42	58°	Cloudy, cool; very slight activity	
24	142	60°	Fair, warm; active	
25	236	63°	Fair, warm, windy, active	
26	107	61°	Fair, warm; active	Combined spray
27	174	55°	Cloudy, cool; some active	
28	202	58°	Fair; active	
29	105	64°	Fair, warm; active	
30	94	63°	Muggy; active	
31	78	57°	Cloudy, rain, warm; slight activity	

The bees showed the same reaction toward the combined spray as was noted in 1925. They were noticeably repelled, particularly while the spray remained as drops upon the blossoms. No such repellent action was noted when lead arsenate was used alone. Figure 2 shows the mortality curve of the bees in relation to the spray applications made.

It will be noted that there was a sharp rise to a high peak of mortality following the first lead arsenate spray. There was also a sharp rise, although not so great, the second day following the second lead arsenate spray. The slightly increased mortality two days after the second combined spray may be due in part to the spray but appears to be more closely correlated with the rise in temperature conditions.

There were four high peaks of mortality reached during the experiment, as follows:

May 13.	237 dead.	Av. temp. 68°F.	No spray involved.
May 18.	325 dead.	Av. temp. 73°F.	Following lead arsenate.
May 25.	236 dead.	Av. temp. 63°F.	Following lead arsenate.
May 28.	202 dead.	Av. temp. 58°F.	Following combined spray.

The peaks of the 13th and 25th were practically the same; occurred at temperatures of only 5° difference and under conditions which would appear to give no significance to the lead arsenate spray which had been applied three days previously. There is one difference, however; the peak of May 13 was at the culmination of a steadily rising temperature for two or three days; the peak of the 25th occurred after the average temperature had fallen for two days and had then risen but a degree or two. Both peaks, however, followed the resumption of activity of the bees after a period of but slight activity, lasting one to two days; so that, while the

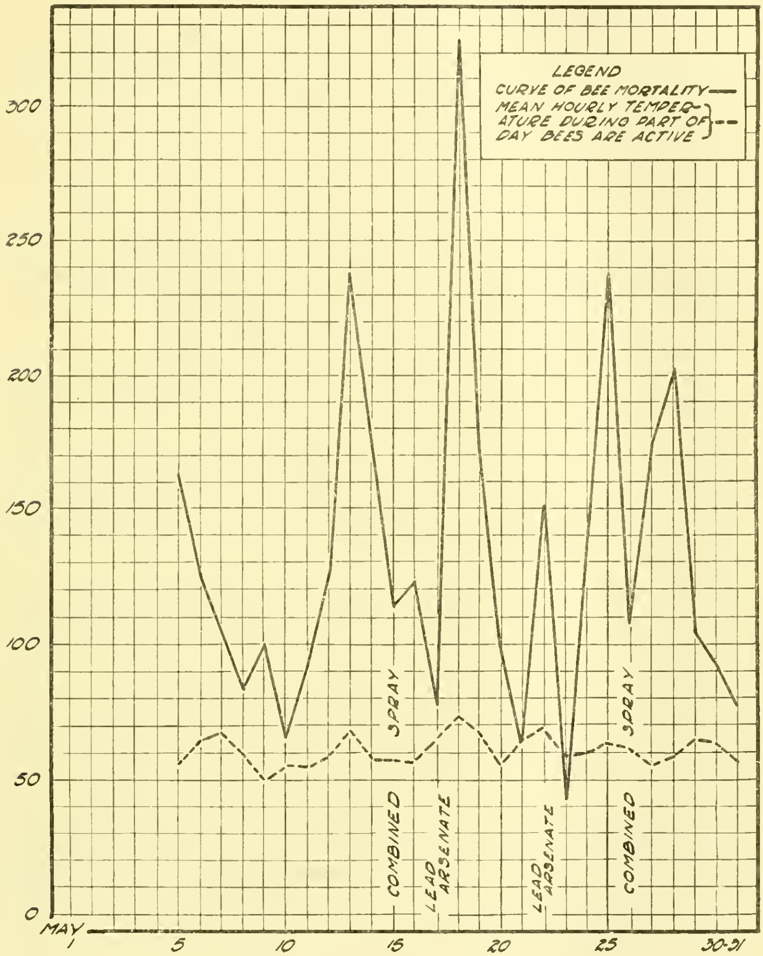


Figure 2. Daily Mortality of Honey Bees in Relation to Experimental Sprays, 1926.

rise of the 25th may have been influenced by the spray, the effect was so slight as to raise some question. The peak of the 28th so closely matches the rise of daily temperature, and besides was so little higher than some other figures reached when no spray was involved, that but little significance can be given it.

The high point reached on the 18th was so abrupt, so close to the lead arsenate spray and represented so great a kill, it must be given some consideration and was the only mortality of any real significance.

Summary

Bees offered equal parts of honey and the regular spray combination (lead arsenate 1½ lbs. to 50 gals., lime-sulfur 1:40, and nicotine sulfate 1:1000) were strongly repelled. This combined spray was, however, very toxic to bees and very rapid in its action.

Lead arsenate spray with honey was readily accepted by the bees. A one-frame nucleus which fed on this mixture lost approximately 50 per cent of its bees within forty-eight hours after feeding. Lead arsenate alone or combined with any of the other materials was very toxic to bees.

Any mixture containing nicotine sulfate was very repellent to bees and was fed on but sparingly. In laboratory experiments, this repellent action persisted for at least forty-eight hours. In the orchard the period was somewhat shorter, due probably to more rapid volatilization of the nicotine.

Bees in a nucleus, placed in a greenhouse and offered bloom sprayed with the orchard combination, were at first repelled, but finally worked the flowers and suffered a very heavy mortality; indicating that with no unsprayed blossoms available bees will work sprayed bloom.

In orchard experiments, contrary to what might be expected from the above, neither a late pink nor an early calyx spray, applied when there was considerable bloom on the trees, caused any serious mortality to colonies located in the sprayed orchards. This was due, in the one case, to the fact that the trees came into bloom very quickly after the late pink was applied, thus affording abundance of unsprayed blossoms; and in the other, to the fact that, since bees have a tendency to forage over a considerable area, the repellent action of the early calyx spray caused them to work bloom in nearby orchards.

In the tent experiments, there was no high mortality except immediately following the application of lead arsenate alone. This was in a measure due to unfavorable weather conditions. It was also due to uneven opening of the bloom. There was always a supply of unpoisoned blossoms available, upon which bees repelled by the combined spray could work. Since lead arsenate was not repellent to the bees, they were not reluctant to work bloom upon which it alone had been sprayed, and consequently were poisoned.

The experiments indicate that, if the recommended combination of lead arsenate, lime-sulfur and nicotine sulfate is used, spraying should have no appreciable effect upon colonies not subject to any restrictions of flight This is true even when some bloom is present, unless improperly timed spraying is carried out on a large scale.

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AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 235 APRIL, 1927

FARM TAXES AND ASSESSMENTS IN MASSACHUSETTS

By Hubert W. Yount

The increasing cost of government brings about a two-fold tax problem: first, equable distribution of the tax burden; second, getting value received for tax money spent. This bulletin concerns itself primarily with the former phase of the problem, particularly as represented by assessment practices in different towns. The second part of the problem will be dealt with in a later publication.

Requests for bulletins should be addressed to
AGRICULTURAL EXPERIMENT STATION
AMHERST, MASS.

SUMMARY.

1. Farm real estate on 214 farms in 1923 was assessed at 53 per cent of the owners' valuation.

2. The average ratio of the assessed value of farm real estate to the owners' value varies as much as 20 per cent between towns.

3. Farm real estate within the same town was assessed at from 30 per cent to 100 per cent of the value as reported by farmers.

4. Livestock was assessed at 65 per cent of its value as estimated by farmers in 1923. The ratio of assessed to reported values of livestock varied as much as 60 per cent between neighboring farms.

5. Reports from 133 boards of assessors show wide differences between towns in the estimated assessed value of land of a similar quality and use. Differences between neighboring towns are as great as between sections of the state.

6. Similar reports from assessors on the assessment of livestock show little uniformity, even in adjacent towns.

7. Urban and industrial real estate is assessed at a higher percentage of value than farm real estate.

8. The percentage of farm income required to pay taxes varies with the farm, the town and the season. In 1923 taxes on 207 farms took 9.76 per cent of the farm income before paying taxes.

9. When computed on a similar basis, taxes take a larger share of the Massachusetts farmer's income than of the incomes received by certain other industrial or professional classes.

FARM TAXES AND ASSESSMENTS IN MASSACHUSETTS[1]

By Hubert W. Yount

INTRODUCTION.

Taxes rank third in importance as an expense on Massachusetts farms, being exceeded only by the costs of feed and labor. The total tax bill on the average farm amounts to from $150 to $200, and is a direct out-of-pocket cost. It falls due on a certain date, and in practice is paid all at one time. Furthermore, taxes are not like other costs, since there is apparently no immediate return. Money spent for labor or feed shows visible results, but the returns from taxes are often intangible, and frequently are distributed over a period of years. This is one reason why there are more complaints about taxes than about other farm costs. It is difficult for the average citizen to see the dollars-and-cents value of improved roads, good schools, police and fire protection, and other government services, especially when he has enjoyed these benefits for a long time. Much of the criticism of high taxes in recent years has been due to the failure of taxpayers to appreciate the increasing cost of government service to which they have become accustomed.

At the outset the problem of farm taxation in Massachusetts presents certain difficulties. The state is industrial, not agricultural; urban, not rural. For this reason tax authorities have paid little attention to farm taxes or farm assessments.

The relative importance of agriculture is shown by the following census figures. According to the United States Census of Wealth, Debt and Taxation, the total wealth of Massachusetts was estimated at $12,980,839,000 in 1922. According to the United States Census of Agriculture in 1925, the value of farm property in the state was $293,405,000, divided as follows:

Land and Buildings	$254,603,000
Implements and Machinery .	17,044,000
Livestock	21,758,000

Assuming the same amount of agricultural wealth in 1922 as in 1925, the value of all farm property was 2.26 per cent of the total wealth of the state. The value of taxable farm property was approximately the same percentage of total taxable property. (1)[2]

The assessed valuation of towns of less than five thousand population is only 9 per cent of the total state valuation, while the city valuation is 74 per cent. Naturally, more attention has been given to assessments in cities and large towns. The number of people who pay farm taxes is also comparatively small. The 1925 Census reported about 149,000 persons living on 33,000 farms in Massachusetts out of a total population of 4,144,000. Therefore farm population is only 3.6 per cent of the total population.

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[1] This is the first of two studies dealing with Farm Taxation, carried on under a cooperative agreement between the Bureau of Agricultural Economics of the United States Department of Agriculture and the Massachusetts Agricultural Experiment Station.

[2] Figures in parenthesis refer to the Appendix.

On the other hand, farm property is more widely distributed than other forms of taxable property. Out of the 355 cities and towns of the state, 242 have less than 5000 population, and this group is principally rural. Therefore the problem of assessing property in two-thirds of the towns of the state is largely a question of the valuation of farm property. In addition, there is farm property in practically every city and large town.

Taxes Paid by Farmers.

Taxes are compulsory contributions levied against the property or citizens of a state for the support of government. They should be levied on the taxpayer in accordance with some accepted principle of justice which may be either his ability to pay, or the benefits he receives from government. In Massachusetts, taxes are supposedly levied according to the ability to pay. This ability is measured by income in the case of the income tax, and by value of property owned for property taxes. For a few public functions, taxes are levied according to benefits received. Street paving, sewers, sidewalks and public water supply are in this class, but payments for these items are usually called special assessments instead of taxes.

Most taxes paid by Massachusetts farmers are for the general support of local and state governments and are levied according to ability to pay as measured by the value of property owned. Taxes levied on this basis are called general property taxes because originally they were levied against all kinds of property. With the development of corporation, income and other new taxes, a great deal of property has been exempted from local taxation, so that Massachusetts really has a modified property tax rather than a general property tax. In spite of this change, however, property taxes still make up over 76 per cent of all state and local taxes, including motor registration fees.

The four types of taxes for which Massachusetts farmers are responsible are as follows:

1. A poll tax of $2.00 is levied on every male inhabitant of the state over 20 years of age.

2. The property tax is the most important tax paid by farmers. Under this tax all farm and personal property, with certain exemptions, is assessed at its fair cash value as of April 1 each year, in the town where located, and taxed at a uniform amount per thousand dollars of valuation, called a rate.

3. The state income tax is a tax levied upon income from certain investments, and from business and professions. Farmers pay a tax of 1½ per cent on their net incomes over $2000, with an additional allowance of $500 for a dependent wife or husband and $250 for each child under 18 years of age. Interest and dividends received from investments in other than Massachusetts corporations are taxable at 6 per cent, although there are a number of exemptions of little interest to farmers. Income from the farm business is the principal item upon which farmers pay income taxes, but probably not over 3 per cent of all farmers pay state income taxes.

4. The Federal income tax must be paid on all incomes of $3500 or more if the taxpayer has a dependent wife or husband, or $1500 if without dependents. There is an additional allowance of $400 for each dependent child. In 1923 only 244 farmers who received their entire income from the farm paid Federal income taxes.

In addition to the taxes mentioned above, a large number of farmers pay a registration fee on automobiles. While this fee is not called a tax, it is a charge made by the state for the privilege of driving a motor vehicle, and has been placed so high that to all intents and purposes it is a tax.

Purposes to Which Taxes Paid by Farmers are applied.

The purposes to which the above-mentioned taxes apply vary considerably. The following table indicates the 1925 distribution of each of the taxes.

Purposes to Which Taxes Paid by Farmers Were Applied, 1925

Tax	Local City or Town	County	State	United States
Poll	100%	None	None	None
Property	88.24%	5.42%	6.34%	None
Massachusetts Income	All except cost of collection	None	Cost of collection	None
Federal Income	None	None	None	100%
Automobile Registration Fees	None*a*	None*a*	100%	None

*a*Counties, cities and towns receive entire benefits, however.

The Amount of Taxes Paid by Massachusetts Farmers.

No data are available on the total amount of taxes paid by Massachusetts farmers, but it is possible to make a reasonably accurate estimate by using the farm values reported by the 1925 census of agriculture. The reported census values together with estimated assessed values of farm property are as follows:

	Census Value, 1925	Estimated Assessed Value 1925 (2)
Farm Real Estate	$254,603,000	$130,612,000
Farm Livestock	21,758,000	14,349,000
Farm Implements and Machinery	17,044,000	1,200,000 (other than motor vehicles)
Total	293,405,000	146,161,000

A small amount of household property was also assessed so that the total estimated assessed value of farm property exclusive of motor vehicles was approximately $147,000,000 in 1925. The average tax rate of $28.53 per $1000 valuation gave $4,194,000 as the total property tax paid by farmers on farm property other than automobiles and trucks.

It is estimated that farm automobiles and trucks were assessed at $10,000,000, (3) giving additional property taxes of $285,000. In addition, the registration fees amounted to at least $464,000, (4) giving a total estimated automobile tax of $749,000. A poll tax of $2 was paid by at least 30,000 farmers and farmers' sons, giving $60,000 in poll taxes. Total farm taxes including property, automobile and poll taxes are approximately $5,000,000, according to above estimates.

No data are available on the amount of income taxes paid by farmers to the state and Federal governments, but it is probable that such taxes are paid on income from sources other than the farm. Therefore, $5,000,000 may be taken as the best estimate available of total taxes paid by Massachusetts farmers. The average taxes are therefore about $156 per farm for 32,000 farms (5).

This average is low, due to the large number of small farms or farms of low value. In a questionnaire sent out to assessors by the Bureau of Agricultural Economics of the United States Department of Agriculture in 1926, it was found that taxes on 243 farms distributed through 53 towns averaged $340 per farm in 1925. The following table shows actual taxes per farm exclusive of automobile registration fees. Since the acreage of the farms reported is from 30 to 50 per cent above the county averages, the tax per farm is typical only of the larger farms.

TABLE 1.—Taxes on Identical Massachusetts Farms, 1924 and 1925.[a]

County	No. of Towns	No. of Farms	Average Acres per Farm	Average tax per Farm		*Average per cent 1925 tax of 1924 tax*	Number of Farms with		
				1924	1925		Higher Taxes	Lower Taxes	Same Taxes
Barnstable	2	10	56.9	$185.96	$206.35	*110.96*	10	..	..
Berkshire	8	37	190.2	173.58	178.86	*103.04*	23	14	..
Bristol	3	15	79.1	355.22	295.46	*83.18*	10	5	..
Dukes	3	13	82.6	109.40	115.11	*105.22*	8	5	..
Essex	5	25	90.0	351.01	352.94	*100.55*	6	9	10
Franklin	2	10	98.8	158.41	159.88	*100.93*	3	1	6
Hampden	2	8	106.1	391.04	392.13	*100.28*	3	..	5
Hampshire	1	5	207.2	82.66	92.13	*111.46*	5	..	..
Middlesex	8	36	105.1	981.32	1018.91	*103.83*	18	13	5
Nantucket	1	3	140.0	120.51	140.75	*116.80*	3	..	..
Norfolk	1	4	34.5	327.12	346.68	*105.98*	4	..	..
Plymouth	5	23	60.2	204.95	199.70	*97.44*	14	9	..
Worcester	12	54	133.8	205.12	203.27	*99.10*	21	26	7
Total	**53**	**243**	**115.0**	**336.30**	**340.28**	**101.18**	**128**	**82**	**33**
Total omitting Middlesex County	**45**	**207**	**116.7**	**224.12**	**222.25**	**99.16**	**110**	**69**	**28**

[a]Data collected by Bureau of Agricultural Economics, United States Department of Agriculture, from local town assessors.

If Middlesex County is omitted from the average, due to the large number of greenhouses and market garden farms reported, the average tax per farm on the remaining 207 farms was $222.

ASSESSED VALUATIONS.

Since property taxes are levied upon the value of property owned, the determination of such value is the basic problem in our system of taxation. The property taxes levied on any individual property change for only two reasons.

1. A change in the amount of taxes raised by the city or town;
2. A change in the assessed valuation of the property.

Most Massachusetts farmers live in towns where public expenditures are voted in open town meeting. Therefore each voter has a voice in determining the amount spent by his community. He has less to do with determining the assessed value of his property, since he is usually not consulted in the matter. The local board of assessors places a valuation on property, and while there are legal methods by means of which improper assessments may be changed, the process of getting an abatement is not easy.

Accurate valuations are dependent upon careful judgment, broad knowledge of local property values, and knowledge of the things which make local property valuable. Assessments will be fair and equitable only to the extent that the local assessors have the necessary knowledge, are honest and painstaking, and have the courage to apply their knowledge and judgment to all taxpayers alike.

According to law, "all property, real and personal, situated within the commonwealth, and all personal property of the inhabitants of the commonwealth wherever situated, unless expressly exempt, shall be subject to taxation." Such property shall be assessed at its "full and fair" cash value as of April I each year. In order to assist the assessors, taxpayers may bring in sworn lists of their property and its value, which the assessors must accept as true, except for the valuation.

In Massachusetts the board of assessors, usually consisting of three men, is much more powerful than similar township boards in states outside of New England. In practice, very few people turn in lists of their property and the assessors must therefore list and value all property. They also act as a board of review and have power to revise assessments upon complaint of the taxpayer. They perform the same functions as the auditor in other states in levying or assessing the tax, that is, apportioning the total tax to be raised among the various persons and properties assessed. It has been said that the Massachusetts boards of assessors "perform the functions and have the powers of assessors, auditors, equalizers, local boards of review, and local boards of appeal."[3]

With all of these powers combined in the same group of men, it is likely that some injustice will occur. Inequalities in assessments are not easily corrected where assessors pass judgment on their own valuations as boards of review or in actions for abatement. Consequently the following inequalities in assessment are likely to occur:

1. Property may be undervalued throughout the town.
2. The ratio of assessed to true values may vary greatly between towns.
3. The ratio of assessed to true values may vary greatly between individual property owners in the same town.
4. Certain types of property may be relatively over- or undervalued.
5. Some property may not be assessed at all.

Undervaluation.

Although the law specifies that property shall be taxed at its full and fair cash value as of April 1, in most towns assessed values are considerably below market value. According to estimates of various tax authorities, property for the state as a whole is not assessed at more than 75 per cent of its actual value. In the United States Census of 1922 on Wealth, Debt and Taxation, it was estimated that Massachusetts property was assessed at 77.6 per cent of fair value. This figure was based on estimates by state and local authorities.

According to law, savings banks are not authorized to loan upon the security of real estate more than 60 per cent of the value of such real estate. However, it is a common occurrence for bank loans to exceed the assessed value of the property. Commenting upon this situation in a special letter to assessors under date of February 9, 1926, the Tax Commissioner says:—

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[3] United States Bureau of the Census. Digest of State laws relating to Taxation and Revenue, 1922, p. 179.

> It is plain in such cases that either the officers of the bank or the assessors have grievously erred. There seems to be a widespread belief that assessors generally do not begin to value property at "its full and fair value." It is strikingly evident that investment boards of savings banks, who deal with at least 40 per cent of all real estate in Massachusetts, in the shape of mortgages, pay no attention whatsoever to valuations placed by assessors . . . . . The assessors' valuations are seemingly held in low esteem. The only course left open when the Courts and the Legislature indicate a feeling that assessors are not valuing property at its full and fair cash value, is for the assessors themselves to set their house in order by making a real effort to value property in accordance with the law and by so doing not only fulfil their oath of office, distribute more equally the burden of taxation, but as well bring back to a position of respect the valuations made by assessors.

While it is true that assessed values are often below first mortgage loans, it is not fair to assume that savings bank loans should be only 60 per cent of assessed values. The basis on which the savings bank loan is made is not always the same as that on which assessments are made.

In the smaller towns, especially, under-assessment is the rule rather than the exception. Few assessors admit assessing at less than 60 per cent of actual value, but property in most towns and cities is assessed below 75 per cent of its cash value, and in some cases at about half value. This is particularly true where there are few actual sales to guide the assessors in estimating a fair value.

The Basis of Appraisal.

Assessment is merely appraisal for purposes of taxation. Appraisals by assessors, savings banks, land banks, real estate agencies, and property owners are all for the purpose of determining "value."

Evidently value varies with the individual appraiser. Three things are usually considered in determining "fair value."

1. Present market value or the possibility of resale.
2. Productive value, based on earning power.
3. Speculative value, or probable value in the future.

The man looking for a farm on which to make a living is interested in the productive value of the property. He does not care about resale value or future speculative value. The bank making a loan on property must consider resale value in addition to productive value. Practice varies with the bank, but some banks also consider the character and reputation of the borrower, and to some extent the probable increase in the value of the property on which the loan is made. They must also consider the possibility of foreclosure and the price at a forced sale. Assessors do not consider speculative value, and sale value is not always a good basis for assessments. Too many current sales anticipate future values and are consequently above productive value. Productive value appears to be the most important factor considered by assessors; at least, assessed values appear to follow productive values closer than sales values, although both are considered in making assessments. In any case, assessed values are evidently less than either sales values or valuations of property owners, due to differences in the basis of appraisal.

There are certain difficulties connected with the accurate appraisal of farm property in Massachusetts. The numerous types of farming make general rules impossible, since each farm must be considered as an individual business. Dairying is the most common farm enterprise and yet there are thousands of farmers who specialize in orcharding, small fruits, poultry, cranberries, tobacco, onions and market gardening. Many farms combine two or more enterprises, which adds to the difficulty of assessment. Such a wide diversity of farm interests means a similar diversity in farm incomes, costs of production, land values, and consequently, taxes.

The topography of the state and the quality of the land are both disturbing factors. There are fertile valleys and rolling uplands in close proximity to swamp or rocky waste. There are many instances where market garden land worth from $200 to $1000 per acre is located within sight of land worthless for any agricultural purpose. The last agricultural census shows that of a total land area of over 5,000,000 acres, only 46 per cent is in farms, and of the land in farms only 29 per cent is classified as crop land. The average farm is made up of:

Crop land	28.8 per cent
Pasture land	37.0
Woodland not pastured	26.7
Other land	7.5

If all farms were average farms, assessment would be comparatively easy, but the amount and quality of the above types of land vary for every farm, for every town, and for every section of the state.

Of the pasture land, more than one-half is wooded, so that 47 per cent of the land on the average farm is woodland. Only 30 per cent of the total farm area can be cultivated, including tillable pasture land. It is apparent that the 70 per cent of land not cultivated, much of it brush and waste that does not produce lumber or even fire-wood, creates a very definite tax problem in itself.

Assessment of Farm Real Estate.

Farm real estate is assessed at a lower percentage of value than many other classes of property. Sales records are perhaps the best indication of actual values where there are a number of sales over a period of years, but sufficient sales data were not available for analysis. Consequently, owners' valuations have been used with corrections as indicated. The following table shows the relation between values as reported by owners and assessed values of farm real estate on 214 farms in 8 towns for 1923 and for 41 farms in 2 towns for 1922. The values in 8 towns were obtained from farm management records,[4] while in two towns figures were secured through personal interview with the farm owner. The farm management records were obtained by a representative of the college who worked with the farmer in determining a fair value for his farm. Where the reported values were out of line with neighboring property, they were corrected by the farm management extension specialist, based upon his knowledge of the community. These values were secured for more than one year in four of the towns, so that they represent the best information obtainable on farm values in the several towns.

Town No. 1 is the only town of the group in which there have been a sufficient number of farm sales to check the figures given.
Most of the sales were of a speculative nature, several being for the development of a new summer colony, and all sales reported were above conservative values for the farms in question. Assessed values were taken from the assess-

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[4] Records were collected by the Department of Farm Management and the Extension Service, Massachusetts Agricultural College.

ment records in the various towns. The towns are distributed over five counties as follows: Berkshire County, Sheffield and Hancock; Franklin County, Shelburne, Heath, Conway and Ashfield; Worcester County, Sterling; Middlesex County, Littleton and Boxborough; and Hampden County, Granville.

Table 2.—Relation between Owners' Value and Assessed Value per Farm of Farm Real Estate in Massachusetts.

Town Number	1923 Tax Rate	Number of Farms	Owners' Value *a*	Assessed Value	*Ratio of Assessed to Owners' Value (Per cent)*
1	$ 29.50	42	$12,145	$ 7,588	*62.4*
2	22.50	22	8,571	5,053	*58.9*
3	21.30	19	5,894	3,342	*56.7*
4	23.50	29	7,428	3,989	*53.7*
5	24.50	25	4,872	2,547	*52.5*
6	26.00	20	6,100	2,764	*45.3*
7	25.00	47	8,610	3,682	*42.7*
8	21.50	10	12,450	5,224	*41.9*
Total or Average		**214**	**8,407**	**4,455**	**53.0**
	1922	**1922**	**1922**	**1922**	**1922**
9	27.00	22	5,514	2,760	*50.1*
10	28.00	19	6,321	3,803	*60.2*
Total or Average		**41**	**5,888**	**3,245**	**55.1**

*a*Owner's value in each case is the owner's estimate of the value of his property, in some instances corrected by consultation with the farm management agent collecting the facts.

Assessed values averaged slightly more than one-half of owners' values, but the percentage varied with each farm, and with each town, the maximum difference between towns being over 20 per cent. The differences between towns are shown graphically in Charts 1 and 2, in which each bar represents one town. The ten farms in Town No. 8 were assessed at 41.9 per cent of owners' value, but it is doubtful if this number was large enough to be a fair sample. The differences between towns are well illustrated by Towns No. 1 and 7, both of which are good farming towns, and in which the samples taken included a majority of farms in each town. According to the table, farms in Town No. 1 were assessed at 19 per cent more of the owners' value than in Town No. 7, which means that on farms of equal value, with equal tax rates, taxes in Town No. 1 were 46 per cent higher than in Town No. 7. A farm worth $10,000 is assessed for $4277 in Town No. 7; in Town No. 1, the valuation is 46 per cent higher or $6247. This means that with the tax rate at $25.00, taxes are $156 in Town No. 1 compared with $107 in Town No. 7. The difference in taxes was exaggerated in 1923 by a tax rate for Town No. 1 which was 18 per cent higher than that of Town No. 7. The high percentage of assessed value combined with the high tax rate meant that for this one year taxes in Town No. 1 were approximately 72 per cent higher than in Town No. 7. This situation was a temporary one, however, as the tax rate in Town No. 1 has been falling since 1923.

The other towns of the table do not vary a great deal from the average, but the variations are sufficient to make a noticeable difference in taxes. It is not to be expected that all farmers pay equal taxes on similar property; this would necessitate equal tax rates, and taxes and tax rates depend upon the

CHART 1. The Relation Between Average Assessed Valuation and Owners' Valuation of Farm Real Estate in Eight Massachusetts Towns, 1923.

Each bar represents the average value per farm of farm real estate in one town. The dark portion of the bar shows the average assessed valuation of real estate per farm in each town. See Table 2.

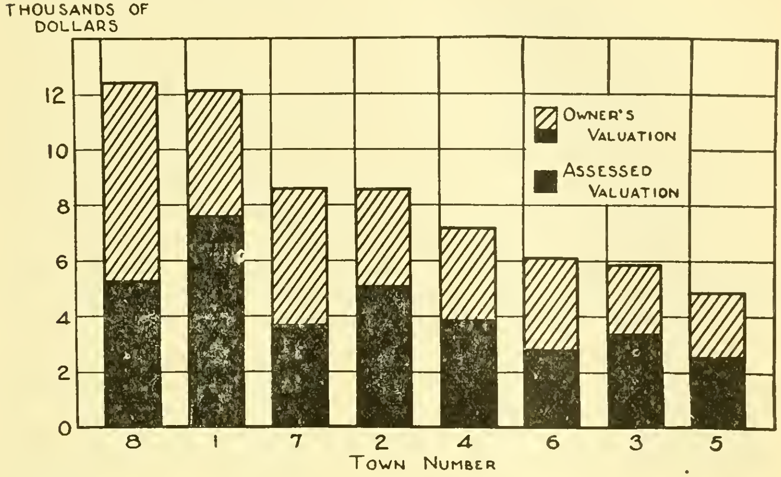
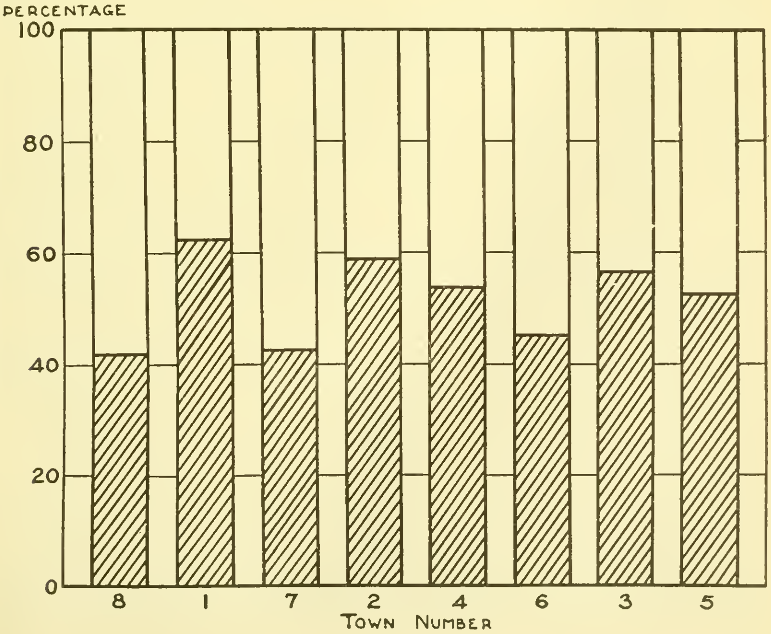


CHART 2. The Ratio of Assessed Valuation to Owners' Valuation of Farm Real Estate in Eight Massachusetts Towns, 1923.

Each bar shows the average percentage of owners' valuation at which farm real estate is assessed in the individual town. See Table 2.



town expenditures. It is to be expected, however, that property of approximately similar character and value will be assessed at the same figure in every town. The high percentage of assessed to owners' value in Town No. 1 is due partly to the numbers of farms and village homes used for residences by city workers, partly to the exaggerated market value of land in orchards, and partly to the general revaluation of property brought about by heavy expenditures for highways and schools.

The principal effect of differences in the ratio of assessed to owners' value as shown above is to cause towns with high assessed values to pay more than their share of state and county taxes. If all property within a town were assessed at a uniform percentage of fair value, the difference between towns would not be important so far as town taxes were concerned. The local tax rate per $1000 of assessed valuation depends largely upon the amount of money voted at the town meeting. The amount is first voted and then levied against available assessed property. The state and county taxes are apportioned in a different way, but the amount per town depends upon the assessed valuation. The following illustration will make this clear.

	Town A	*Town B*
Actual Value of Taxable Property	$2,000,000	$2,000,000
Ratio of Assessed to Actual Value, per cent	40	60
Total Assessed Valuation	800,000	1,200,000
Town Tax	20,000	20,000
Tax Rate based on Town Tax	25.00	16.66
State tax at $2.00 per $1000 Assessed Valuation	1,600	2,400
Town and State Tax	21,600	22,400
Tax rate based on State and Town Tax	27.00	18.66
Rate per $1000 on Actual Value	10.80	11.20

In actual practice the State Tax Commissioner attempts to equalize state taxes in such cases by equalizing the property valuations. As there is no available information on the extent to which property is undervalued in any given town, equalizations are only approximate.

The tax requirements of various towns are more uniform than assessment practice. Therefore it is to be expected that where there is considerable difference between the ratio of assessed to owners' value, the towns assessed at a low percentage of value will have a relatively high tax rate. The table above shows this to be the case if we except Town No. 1, which had been reassessed and Town No. 8, in which the number of farms was too small for a fair sample. For the remaining towns the relation is as follows:

Town	Tax Rate	*Ratio of Assessed to Owners' Value (Per cent)*
6	$26.00	*45.3*
7	25.00	*42.7*
5	24.50	*52.5*
4	23.50	*53.7*
2	22.50	*58.9*
3	21.30	*56.7*

It is apparent that low tax rates are accompanied by a high ratio of assessed to owners' value. Unusual appropriations in any given year throw the tax rate for any given town out of line; but on the average, high tax rates in rural towns are a fair indication of underassessment.

Inequalities in Assessment between Farms.

Inequalities in assessments between farms within the same town are of much more importance than inequalities between towns. It has been shown that differences between towns cause higher or lower state and county taxes, but have little effect on the total tax paid by the individual farmer. Assessment differences between farmers in the same town are reflected in high or low taxes. The ratio of assessed to owners' values varies more between neighboring farms than between towns. Thus in Town No. 7 where assessments were 43 per cent of owners' values, individual farms were assessed at from 25 to 80 per cent of their values. The range was still greater in Town No. 1, being from 37 to more than 100 per cent, three-fourths of the farms being assessed between 40 and 80 per cent of owners' value. The other towns show similar variations. Table 3 and Charts 3 and 4 show the number of farms assessed at varying percentages of owners' value for Towns No. 1 and No. 7 as well as for 184 farms in six towns. It will be noted that while there are wide differences within each town, assessments in Town No. 7 are uniformly lower than in Town No. 1. The summary for six towns includes farms from towns in which assessed values are relatively high and low, and may be regarded as fairly typical of the state. The range from less than 20 per cent of owners' value to more than 100 per cent is greater than is likely to exist within any one town, and it is probable that both the very high and very low assessments are due to errors in the data. Omitting the extremes, over 85 per cent of the farms are assessed at from 30 to 80 per cent of owners' value. Such a range within a town means that for every $100 in taxes paid by the farmer assessed at 30 per cent of fair value, the farmer assessed at 80 per cent would pay $266.

TABLE 3.—Farms Grouped According to the Ratio of Assessed to Owners' Valuations of Farm Real Estate

Ratio of Assessed to Owners' Valuation (Per cent)	NUMBER OF FARMS Town No. 7	Town No. 1	Total for Six Towns
10.0 - 19.9	0	0	3
20.0 - 29.9	7	0	8
30.0 - 39.9	11	3	23
40.0 - 49.9	14	8	43
50.0 - 59.9	10	11	43
60.0 - 69.9	2	7	31
70.0 - 79.9	2	8	24
80.0 - 89.9	1	3	7
90.0 - 99.9	0	1	1
100.0 -109.9	0	1	1
Total	**47**	**42**	**184**

The remedy for such inequalities is frequent revaluation and more careful assessments based on definite knowledge of factors affecting property values. In too many rural towns assessed values have not been changed for years; in some cases not for generations. An instance was recently reported where the assessment of a farm in southeastern Massachusetts had not been changed

CHART 3. The Relation Between Assessed and Owners' Valuation of Farm Real Estate for 184 Farms, Showing the Number of Farms Assessed at Different Percentages, 1923.

Each dot on the chart shows the number of farms, the real estate of which was assessed between certain percentages of the owners' valuation. Most farms were assessed between 40 and 59 per cent of the owners' valuation.

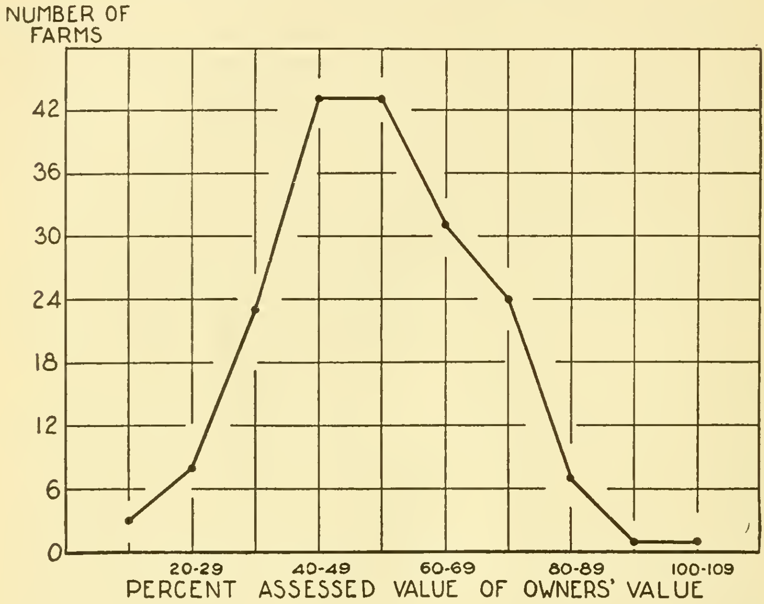
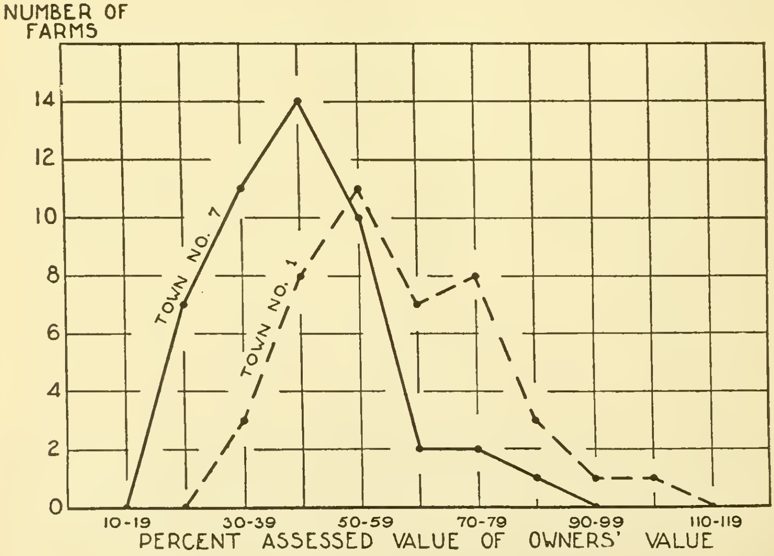


CHART 4. The Relation Between Assessed and Owners' Valuation of Farm Real Estate for Two Towns, Showing the Number of Farms Assessed at Different Percentages in Each Town, 1923.



in nearly 100 years. In the Connecticut Valley, where some of the best farm land in the state is located, the assessed valuations of many parcels of high-priced market garden, tobacco and onion land have not been revised for ten or fifteen years. In other towns assessments have been revised as property values increased, with inequalities between towns as the result. Occasionally assessors will revalue a property only after a sale, and in such cases there is resulting inequality between properties in the same town. New buildings are usually valued at a higher percentage of their actual value than old buildings. As a result, farm property with good, well-kept buildings is valued at a higher percentage of actual value than farms with old buildings. This was shown by the records in every town with sufficient records to furnish a fair sample.

This is partly accounted for by the fact that old farm buildings were assessed years ago, when building costs were low. In most small towns the depreciation on buildings is not considered, nor is any real attempt made to measure appreciation in value for the farm as a whole. If a normal depreciation charge were made against the original value of many of our farm buildings they would be worthless, but appreciation in the dollar value of the farm as a whole has more than offset depreciation of buildings in many cases. Actually many farm buildings are worth considerably more today than when they were built, while those constructed during the war have fallen in value due to abnormal building costs during that period.

One difficulty in assessing farm property is that the division between land and buildings must be rather arbitrary. In some localities the buildings alone are worth as much for residence purposes as the entire farm, while in other instances the land is the valuable item and the farm is worth as much without the buildings as with them. The usual method of valuation is first to determine the value of the farm as such and then to make an arbitrary division between land and buildings.

Assessment of Livestock.

Assessed values of livestock vary even more widely from market values than do real estate values. Table 4 shows the variations between assessed and owners' values of the taxable livestock on the farms previously considered. Assessed values averaged 65 per cent of owners' value, or about 12 per cent higher than for real estate. Averages for individual towns varied from 51 per cent in Town No. 7 to 80 per cent in Town No 3. Livestock assessments in the dairy towns in the eastern end of the state averaged about 66 per cent of

TABLE 4.—Relation Between Owners' Value and Assessed Value of Taxable Livestock per Farm in Massachusetts in 1923.

Town Number	1923 Tax Rate	Number of Farms	Owners' Value	Assessed Value	*Ratio of Assessed to Owners' Value (Per cent)*
7	$ 25.00	50	$ 2,138	$ 1,081	*50.5*
3	21.30	21	1,372	1,103	*80.3*
5	24.50	26	1,422	993	*69.8*
2	22.50	22	3,224	1,926	*59.7*
4	23.50	28	941	640	*67.9*
1	29.50	42	1,814	1,178	*64.8*
Total or Average		**189**	**1,832**	**1,126**	**61.5**

owners' value. Inequalities between farmers in the same town were greater than in the case of real estate, assessed values varying from 35 to 100 per cent of owners' values in many towns. The usual range is from 50 to 75 per cent. Livestock on heavily stocked farms is assessed proportionally lower than on the farms with little livestock. In order to show this conclusively, the farms were ranged in order according to owners' value of taxable livestock (the smallest value at the top, the next smallest second, and so on). The ratio of assessed to owners' value was calculated for each group above and below the center or median farm. The results are as follows:

	Owners' Value of Taxable Livestock	Assessed Value of Taxable Livestock	*Ratio of Assessed to Owners' Value (Per cent)*
Lightly stocked farms	$85,873	$59,143	*68.87*
Heavily stocked farms	260,377	153,637	*59.00*

As livestock in Town No. 7 was assessed at a lower percentage of value than in the other towns under consideration, it was thought that the preponderance of low figures might distort the data. Accordingly, the figures for 50 farms in Town No. 7 were ranged separately, as follows, in order to see if the principle held by towns.

	Owners' Value of Taxable Livestock	Assessed Value of Taxable Livestock	*Ratio of Assessed to Owners' Value (Per cent)*
Lightly stocked farms	$28,224	$16,350	*57.92*
Heavily stocked farms	78,699	37,725	*47.93*

It will be noted that the heavily stocked farms are assessed approximately 10 per cent lower than the lightly stocked farms in each case. This difference of 10 per cent in the ratios actually means that the lightly stocked farms pay, on the average, 16 per cent more taxes on their livestock than the heavily stocked farms; and for Town No. 7 the difference is more than 20 per cent.

Assessment Differences as Reported by Assessors.

The preceding discussion has been based on data from a limited number of farms in five counties representing only 2 per cent of the towns. In order to verify these conclusions and obtain futher information on differences in assessment practice with regard to farm property, questionnaires were sent to 340 boards of assessors. Data were asked for as to the usual assessed value per acre of land used for hay, pasture, woodland, orchard, market garden and tobacco, onions and cranberries where grown. The usual assessed values for dairy cows, horses and fowls were also requested. The valuations of hay and pasture land were divided into good, average and poor; the same classification was used for dairy cows.

Schedules were returned from 133 towns and cities. In most cases real attempts were made to give accurate estimates, although, as many assessors wrote, in assessment practice farm land is not separately valued according to use. Regardless of this objection, many boards of assessors do consider the various uses to which land is put even when valuing the farm as a whole. In assessing land in the Connecticut Valley, assessors in Massachusetts and Connecticut usually keep a record of the land used for tobacco, and such land is assessed at a higher value per acre than hay or other cultivated land. From inspection of assessment books it was found that brush and waste land, as well as woodlot, were considered in making assessments. Therefore, while the assessors do not actually separate land into the classes shown in the table below, it is believed that the averages shown based on the original replies indicate in a general way the differences in assessed values in various sections. The division of the state into the sections shown is purely arbitrary, and is used in order to group towns, alike as to topography and agriculture. The Metropolitan group includes cities and towns in the metropolitan area close to Boston. The Eastern group includes towns in Middlesex, Essex and Norfolk counties not in the Metropolitan district. Bristol and Plymouth counties make up the Southeastern section, while the Cape includes Barnstable, Dukes and Nantucket counties. Each section includes sufficient towns to be typical of the area. The results of the survey are shown in Table 5 following.

TABLE 5.—Assessed Value of Farm Land in Massachusetts According to Use, 1926. (Dollars per Acre)[a]

	Western	Connecticut Valley	Central	Metropolitan	Eastern	Southeastern	Cape	State
Hay Land								
Good	$46	$74	$55	$172	$93	$107	$77	**$83**
Average . . .	26	54	36	190	64	83	47	**61**
Poor	15	27	20	37	31	37	32	**28**
Pasture Land								
Good	18	20	20	..	45	34	40	**37**
Average . . .	12	16	15	154	33	44	24	**35**
Poor	7	9	8	..	20	16	13	**14**
Wood Land								
Woodlot . . .	16	31	49	101	47	60	21	**43**
Brush	6	8	8	59	18	14	7	**14**
Mountain or Swamp . . .	4	5	5	30	10	6	5	**7**
Orchard								
Non-Bearing . .	57	58	44	52	61	79	84	**62**
Bearing . . .	150	111	115	95	110	265	130	**139**
Market Garden . . .	..	135	92	533	121	130	115	**176**
Tobacco or Onions . .	..	118	..	..	..	..	..	**118**
Cranberry Bog . . .	..	..	..	..	..	435	255	**296**

[a] As reported by Boards of Assessors in reply to a questionnaire sent out by the college.

It will be noted that there are great differences in assessed values for the same kind of land. This may be partly accounted for by the definition of the terms used in the questionnaires. Good mowing land to the assessor in a hill town may not be the same to the assessor on the rolling lands of the eastern part of the state. However, the figures are a rough measure of the differences in assessed value and reflect in some degree differences in actual value between the sections. In fact, the differences in the averages as given follow the differences in Census values in a general way. The averages for livestock are low everywhere, but show considerable difference between the eastern and western parts of the state.

The assessed values of dairy cows in 119 towns are shown in Table 6. The wide differences in assessors' estimates as to the value of an average dairy cow indicate that average livestock assessments bear little relation to value.

TABLE 6.—Assessed Values for Average Dairy Cows and for Chickens, 1926*a*

Value per Cow (Dollars)	Number of Towns	Value per Fowl (Dollars)	Number of Towns
$20—29	1	$.50— .74	5
30—39	3	.75— 99	3
40—49	24	1.00—1.24	73
50—59	45	1.25—1.49	7
60—69	21	1.50—1.74	14
70—79	15	1.75—1.99	1
80—89	3	2.00 and over	2
90—99	0		
100—109	7		
Total	**119**	**Total**	**105**

a As reported by Boards of Assessors in reply to a questionnaire sent out by the college.

An examination of the assessment books of numerous towns shows that assessors commonly have a level of values for dairy cows and that most of the cattle within the town are assessed at this level. Usually there are three common values,—for cows, for 2-year-old heifers, and for young stock over one year. If the assessed value for cows is $40 per head, 2-year-olds will probably be $30 and yearlings $15. Very little difference is made between the high-priced purebred cow and the low-producing grade cow unless an entire herd is made up of purebred stock. It will readily be seen that an assessed valuation of $40 per head for dairy cows in one town and $60 per head in the next town may mean a 50 per cent higher cattle tax to the dairy farmer in the town with the high valuation if the tax rates are equal.

TABLE 7.—Assessed Value of Livestock in Massachusetts, 1926. (Dollars)*a*

Section	Dairy Cows			Horses	Chickens
	Good	Average	Poor		
Western	$78	$45	$32	$97	$.95
Conn. Valley	73	52	32	103	1.03
Central	83	54	35	94	1.08
Metropolitan	92	67	40	120	1.23
Eastern	88	55	36	97	1.15
Southeastern	92	64	38	92	1.10
Cape	87	66	43	96	1.18
State	**85**	**57**	**36**	**99**	**1.10**

a As reported by Boards of Assessors in reply to a questionnaire sent out by the college.

Some towns assess poultry as low as 50 cents per fowl, but $1.00 is the most common figure. Table 6 shows differences in assessed value of from 50 cents to $2.00 per fowl.

Assessment Differences According to Type of Farming.

The fact of inequalities in farm assessments between towns and between farms in the same town has been demonstrated. It remains to be seen whether these inequalities apply to all farms alike or whether certain types of farm are discriminated against more than others.

Since livestock is assessed at a higher percentage of its value than real estate, it might be supposed that dairy farmers as a class pay relatively higher taxes than fruit growers, market gardeners, or poultrymen. So far as the average dairy farm is concerned, this is not true. The livestock on such farms does not form a sufficiently large part of the total taxable investment to make an appreciable difference in the average. Out of a total assessed value of $5,000, livestock represents less than $1,000 on the average dairy farm. The proportion of taxable livestock to the total taxable investment in six Massachusetts towns is shown in the following table.

TABLE 8.—Taxable Real Estate and Livestock per Farm, 1923

Town	Total Taxable Investment	Real Estate	*Per cent of Total*	Livestock	*Per cent of Total*
1	$15,577	$13,574	*87.13*	$ 2,003	*12.87*
2	12,223	8,912	*72.91*	3,311	*27.09*
3	7,944	6,333	*79.72*	1,610	*20.28*
4	11,394	10,230	*89.78*	1,164	*10.22*
5	6,241	4,819	*77.22*	1,422	*22.78*
7	11,023	8,824	*80.04*	2,199	*19.96*
Average	**11,230**	**9,270**	**82.55**	**1,959**	**17.45**

In order to determine assessment differences between fruit and dairy farms, forty fruit farms with more than 500 bearing trees were selected and compared with thirty-two dairy farms in the same area. The results are as follows:

	Owners' Value of Real Estate	Assessed Value of Real Estate	*Ratio of Assessed to Owners' Value (Per cent)*
40 Fruit Farms	$475,200	$281,130	*59.16*
32 Dairy Farms	248,250	147,565	*59.44*

It is apparent that there is no difference in the ratio of assessed to owners' values of real estate between the two types of farms. However, values of fruit farms were inflated more than values of dairy farms. The productive value of land used for orchards has been overestimated, and it seems likely that while the owners' values used above were typical of current values in 1923, it was also true that there was an orchard boom at the time. Therefore it seems wise to discount the orchard values to some extent indicating the possibility that orchards were assessed slightly higher than dairy farms.

While the above averages do not show any particular differences, individual instances of inequalities are common. Many large orchards are assessed at from $300 to $400 per acre and it is doubtful if they could be sold at that price at the present time. Table 9 illustrates differences in assessed values for orchards, and it is evident that assessment practice varies widely between towns. While there are not enough instances available to give definite statistical proof of the fact, there is considerable evidence that real estate of specialized fruit farms is assessed proportionally higher than other kinds of farm real estate. This statement is borne out by opinions of men familiar with farm real estate in all parts of the state.

TABLE 9.—Assessed Value of Bearing Orchards and of Market Garden Land, 1926[a]

Average Value per Acre (Dollars)	Number of Towns	
	Bearing Orchards	Market Garden
0 - 49	7	5
50 - 99	17	11
100 - 149	20	29
150 - 199	8	8
200 - 249	5	8
250 - 299	2	4
300 - 349	5	8[b]
Over 350	3	
Total	**67**	**73**

[a] As reported by Boards of Assessors in reply to a questionnaire sent out by the college.

[b] $300 and over.

Poultry farmers as a group have most of their taxable investments in real estate, the largest part of which is buildings. The average poultry farm needs less land than a dairy farm, and is therefore likely to be assessed relatively higher, as buildings are assessed proportionally higher than land. Since very few towns assess poultry at more than $1.00-1.25 per fowl, the value of poultry is a small part of the total assessment.

In the Connecticut Valley, tobacco and onion lands are apparently under-assessed compared with land for other purposes. On the other hand, land used occasionally for tobacco is often assessed at the same value as land in continuous tobacco production, and such assessments are too high. This situation exists in the towns, on either side of the Valley proper, in which tobacco raising is supplementary to dairying and fruit growing. Low prices for tobacco and onions during the past few years have affected sales values of land in the Valley so that the ratio of assessed values to actual values is higher than before.

Market garden land varies greatly in assessed value, depending upon fertility, proximity to cities, and local standards of value. In the suburban districts it is not unusual to find assessed values of $500 per acre, while in the outlying sections values from $100 to $200 per acre are customary. Variations between towns are shown in Table 9. Since market garden land is high in value, a large percentage of the farm investment is in land. The site value of such land due to its location near cities, causes market garden land to be assessed at a lower percentage of sale value than other farm real estate. On the basis of fair value for farming purposes only, market garden land is probably not underassessed more than other farm property.

TABLE 10.—Assessed Values for Average Mowings, Average Pasture Lands and Ordinary Woodlots, 1926*a*

Average Value per Acre (Dollars)	NUMBER OF TOWNS		
	Mowings	Pasture	Woodlots
0 - 9	0	8	5
10 - 19	5	39	19
20 - 29	16	25	28
30 - 39	15	10	7
40 - 49	7	4	7
50 - 59	18	5	18
60 - 69	11	0	0
70 - 79	14	2	6
80 - 89	1	1	0
90 - 99	1	0	1
100 - 109	10*b*	3	11
Over 150		3	2*c*
Total	**98**	**100**	**104**

a As reported by Boards of Assessors in reply to a questionnaire sent out by the college.
b $100 and over.
c Over $270.

Farm Property Exempt from Taxation.

Farmers benefit by exemptions not given to other classes of taxpayers. According to law the farming utensils; mules, horses and neat cattle less than one year old; swine and sheep less than six months old; and domestic fowls not exceeding $15 in value are exempt from taxation. These exemptions benefit the farmer who puts money into farm livestock and equipment. The livestock exemption does not reduce taxes appreciably, due to the small number of young livestock carried and their low value; but the exemption of machinery frequently amounts to more than a thousand dollars, which means a saving of from $20 to $30 in taxes. While not expressly exempt by statute, stocks of feed and supplies are usually not assessed. On the prosperous farm this means the further exemption of perhaps five hundred to one thousand dollars or more. The fact that assessments are as of April 1 reduces this amount on the average farm, since stocks of feed and supplies are low at that time.

For a number of years the exemption of poultry to the amount of $15 meant the practical exemption of all poultry. In recent years the development of poultry raising has caused greater attention to be paid to assessments, with a considerable increase in the number of fowls assessed.

The practical effect of the exemptions noted is to discriminate against the small farmer. Where the farm investment consists principally of real estate and productive livestock, the ratio of assessed to actual value is considerably higher than on the large farm with a considerable amount of exempt property. A comparison of taxes paid on large and small farms is made in the following table, where farms were ranked in descending order of their total investment with the smallest at the top, and the median farm taken as the dividing point. If the taxes paid are computed in dollars per thousand on the entire investment, the large farms in Littleton pay at the rate of $16.81, while the small farms pay $18.09. The differences vary with the town, but the small farms are consistently taxed higher than the large farms.

Table 11.—Relation between Taxes and Investment on Large and Small Farms, Seven Massachusetts Towns, 1922[a]

Town	Total Value of Investment		Total Taxes		Tax Rate per $1,000 Actual Value	
	Large Farms[a]	Small Farms[a]	Large Farms[a]	Small Farms[a]	Large Farms[a]	Small Farms[a]
Sheffield	$448,665	$197,620	$3,697	$1,700	$8.24	$8.60
Heath	120.529	55.095	1.827	844	15.16	15.31
Granville	108,297	59,305	1,506	1,006	13.91	16.96
Ashfield	122,321	50,786	1,714	927	14.01	18.23
Shelburne	269,790	133,438	3,072	1,753	11.38	13.28
Boxboro	255,644	126,195	2,846	1,510	11.13	11.96
Littleton	645,637	197,741	10,856	3,579	16.81	18.09
Total	**1,970,883**	**820,180**	**25,518**	**11,319**	**12.94**	**13.80**

[a] Large and small farms refer to size of farm investment, not to acreage.

Assessment of City Property.

It has been shown that the ratio of assessed to owners' valuations of farm property varies between towns, between farms and between types of farms. Another angle to the same question is the relative difference between assessed and actual values for farm and other property such as business, residence and industrial property in cities and large towns. A generation ago farm property was relatively overvalued and equality of assessment was considered the outstanding farm tax problem of the day. Today the situation is changed.

Property in cities and large towns is generally assessed at a higher percentage of its cash value than property in small towns. This is to be explained by the ever-increasing demand for funds to meet the increasing expenditures of growing cities and towns. Under the spur of necessity boards of assessors in the larger cities and towns are attempting to put assessments on a systematic basis and are beginning to assess by uniform rule rather than by rule of thumb. Zoning systems are gradually being adopted, under which uniform land values per square foot or per front foot are applied to a given area. Allowances are made for special locations, and values decrease with an increase in distance from main streets. Under such a system inequalities in assessed values between neighboring property owners are practically eliminated if the building valuations are made in a similarly careful manner. Particular attention has been paid to assessing factory and corporation property because such property pays a substantial share of taxes in most cities, in several cases over 50 per cent of all taxes levied. It is estimated that for the entire state, corporations of all kinds pay approximately $35,000,000 in local property taxes, or 18 per cent of the total collections. The relative importance of corporation taxes in several cities is shown in the following table.

TABLE 12.—Property Taxes Paid by Corporations in Massachusetts Cities, 1925*a*

City	Total Tax	Tax Paid by Corporations	*Per cent of Total*
New Bedford	$ 5,725,031	$ 3,033,945	*53.0*
Fall River	5,700,566	3,093,965	*54.27*
Lawrence	3,616,929	1,718,326	*47.5*
Lowell	4,623,868	1,877,090	*40.59*
Springfield	8,214,024	2,162,800	*26.56*
Holyoke	2,669,776	1,124,474	*42.11*
Fitchburg	1,737,365	531,098	*30.56*
Worcester	8,994,988	2,094,659	*23.29*

a As reported by Boards of Assessors.

Assessors in at least five cities are finding it profitable to use engineering methods in factory valuations. Several cities are beginning to use accurate measurements of square footage, cost of labor and building materials, original costs of construction, as well as replacement cost, together with the best available information on depreciation charges for various types of buildings and machinery used for different purposes. These efforts are resulting in improved assessments. Small towns have no facilities for such methods; the assessors give only a small part of their time to actual assessment, and factory and corporation assessments in general have been made according to what the traffic would bear, or by taking a figure furnished by the corporation.

Available figures indicate that under these circumstances, corporation assessments are at a higher average percentage of actual value than residential property. Years ago this was not the case. According to a corporation tax expert, fifteen or twenty years ago a great deal of corporate property was assessed at not more than 50 per cent or 60 per cent of its fair value. This was particularly true of public utility companies having wire, pipes, track and other equipment, the value of which depended to a large extent upon the earnings of the company. At the present time assessed valuations of many public utilities average 90 per cent of their book values, which in many cases include the original cost plus any additions without deducting depreciation. The ratio of assessed values to book values of real estate and machinery for nine large gas and electric companies in 1925 was 94 per cent. Actual values of such property are of course difficult to determine. In fact, the value of all factory real estate and machinery is difficult to determine, since it depends upon the earnings of the company, which in turn depend upon successful management. The textile companies in several cities claimed overassessment during the years from 1920 to 1924 and in actions for abatements it was found that several companies were assessed at a figure 20 to 25 per cent above the fair value of their real estate and machinery.

Sales data collected by the Board of Assessors in Springfield show that business property is assessed at about 80 per cent of its sale value. Nineteen parcels in the business section were sold for $3,084,000; the assessed value was $2,467,000, or 79.98 per cent of the selling price. The ratio of assessed to sale value varies of course with the property. A few parcels were assessed for an amount approximately equal to their sale value. Other parcels were assessed as low as 50 to 60 per cent, but most of the assessments ran from 70 to 85 per cent of the sale value.

Twenty-six properties in Springfield used principally for residence purposes were assessed at 74 per cent of their selling price. Assessments are closer to sale value in the older sections of the city, and reports from assessors indicate that this is true in most cities. As with business property, there is considerable variation in the assessments, some property being assessed at only 50 per cent of sale value, while a few parcels were assessed at more than 100 per cent. The number of sales is not sufficient to show more than a rough average. The sales covered a period of one year only and can not be considered a representative sample. Several of the transactions were evidently to relatives, while a few sales were apparently transfers to holding or operating companies under the former management. Since some of the conditions of the sales were unknown, these figures should be considered merely as indicative of the ratio of sales to assessed values.

Further differences between assessed and sales values in various cities are shown in the following quotations from replies to questionnaires made by members of the Massachusetts Association of Real Estate Boards[5].

> "Largest office building in city sold three years ago at less than assessed valuation. In general, central business properties assessed about 80 per cent of present market value. Many instances, however, where assessment is greater than sound value. Speculative sales where owners hold small equities have misled assessors. Readjustment period bound to come and sound values will be less than many of these sales prices." Another correspondent asserts: "Not much attention paid by assessors to real values." Another reports: "In many instances, especially down-town higher than market—suburban property below market value." One says: "Valuations 40 per cent below sales" and they run along thus: "Valuations as a whole come within 70 to 80 per cent of present values, with small dwellings only 50 per cent;" "Nearly every sale in excess of taxed value;" "Assessments much less than market, in some cases 50 per cent;" "In older parts of city assessments higher than asking price but in 75 per cent of cases below actual values:" "Assessments about 66 per cent of sale price;" "Shore assessed 80 per cent of market, inland 60 per cent."

Assessments of apartment houses are more difficult to determine than for some types of city real estate. Market values of such property are often speculative and are likely to be relatively high when compared with total rents Instances have been reported where apartments were returning only 8 per cent of their sale value in gross rents. Assessed values in such cases are lower than sales values and are based on the non-speculative value representing a fair return on the investment. Building lots are assessed at a low percentage of their sale value because frequently sale value is not a fair index of value in a section. A temporary boom, or sale of particular lots for special purposes often tends to inflate values. Assessors consider these facts in the assessment of such property and inflated values are properly discounted.

Causes of Inequalities in Assessment.

The most important cause of undervaluation of farm property is a lack of knowledge of the things which determine values. The assessor has no yardstick with which to measure value. He is told to use his best judgment in determining fair cash value when there is usually very little information on which judgment can be based. The factors affecting property values in cities have been studied and various attempts to put assessments on a systematic basis have been made, but no such attempts have been made to systematize farm assessments.

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[5] Speech by Mr. Henry Whitmore before the Association of Massachusetts Assessors, December 15, 1926. Reprinted in "Instructions to Assessors" No. 7, Massachusetts Department of Corporations and Taxation.

Infrequent valuation is another cause of undervaluation of farm and city property. New property can not be listed and inequalities in assessment between neighbors can not be corrected by copying the valuations of the previous year. Attempts are often made to remedy undervaluation by increasing all assessed values by a uniform percentage. Obviously this method is faulty, since it does not attempt to correct existing inequalities between properties within the town.

Undervaluation of farm real estate often results from an attempt to reconcile the value for farming purposes with the value for purposes other than farming. Under normal conditions, the value of farm land bears a direct relationship to the average income derived from it. In Massachusetts the large and growing urban population makes continuous demands for more room. This means that farm land adjoining our larger cities and towns has a site value for building lots entirely out of proportion to its value as farm land. Farm land for subdivision purposes is worth from $500 to $1000 per acre. Only the best grades of market garden land will return a profit on such high valuations. To assess farmers on the value of their land for building lots may be unfair, since taxes may force such land on the market before it is really needed. Assessors attempt to get around the situation by a valuation somewhere between the farm value and the value for subdivision purposes.

The importance of this type of land will be realized when it is considered that our 39 cities occupy one-tenth of the land area of the state. In addition to the cities there are 79 towns of more than 5000 population, 31 of which are semi-urban with a population of 10,000 or more. It is estimated that 15 per cent of the land area of the state is used for city residence, business and factory purposes. As the population is increasing at the rate of about 2 per cent each year, it is apparent that the amount of farm land going into urban uses each year is comparatively large.

A further reason for the low assessment of farm land compared with sale value lies in the increasing use of farms for residences by city workers. Such farms usually sell for much more than the farm is worth for farming purposes. If the assessed value of such property is raised to approximate its sale value, adjoining property occupied by actual farmers must be raised proportionally thereby working a hardship on the farmers.

A third factor affecting land values is the increasing amount of farm land going into large residential estates. Numbers of farms have been purchased in all parts of the state and have been turned into estates. Where such an estate is being formed, prices of farm land are always higher than the sale value for farming purposes. In certain towns in the eastern part of the state, estates or summer homes make up practically the entire town although the land is assessed at approximately its value for farm purposes. In other cases, assessors have attempted to assess such property between the farm value and the sale price.

In most cases the assessors have made some effort to adjust assessments upward without burdening the farmer too heavily, where the above-mentioned conditions exist. Naturally ideas on how much of the extra-farm value should be included in the assessment vary. Accordingly, one town assesses at 80 per cent, another at 60 per cent, and another at 50 per cent of sale value. Assuming sale value at $500 per acre for subdivision purposes, and a tax rate of $30 in each town, taxes vary as follows:

Town	Assessed Value	Tax per Acre
A	$ 400	$ 12
B	300	9
C	250	7.50

Thus on land of the same use and same sale value taxes may vary 60 per cent.

A further cause of undervaluation has already been suggested in the discussion of appraisal. Assessed values of both farm and city real estate lag behind sales values so that average assessed values are usually below sales values at any given time. In addition, increases in sales values are not followed by immediate increases in assessed values. For one reason, assessments can not be expected to follow every speculative real estate boom. Another reason is that assessments are changed only once each year, giving a lag of at least a year between a general increase in market values and a similar increase in assessed values. In actual practice this lag is from two to five years depending upon the city or town. In small towns the lag is longer than in the larger towns and cities.

Apparently assessed valuations of both farm and city property run closer to earnings than to sale value. During the past twelve years the increase of 60 per cent in assessed values of city real estate has been about equal to the increase in rents paid for residence purposes. During the same period, increases in assessed values of farm lands have been greatest in the market garden, orchard and tobacco raising towns where gross returns per acre have increased most. For the towns in which farm management surveys have been made, assessed valuations of real estate have increased most in towns showing the largest farm incomes. It seems probable that failure to increase valuations in many agricultural towns can be traced to continued low profits in farming even where sales values may have increased due to the demand for summer homes. Apparently there is considerable justification for assessing below sale value in such cases.

One case in which assessed values bear no relation to either sale value or earnings is where real estate values are falling. Assessors are interested primarily in increasing valuations, and consequently assessments are not reduced in proportion to a decline in market value, nor are they reduced at the time such decline occurs. In many cases market values fall below assessed valuations before there is a reduction in assessment. This is true in decadent portions of cities as well as in many small towns. Frequent revaluation is needed in such sections.

Intentional Underassessment.

Aside from the reasons already mentioned, farm real estate and other property in small towns are often intentionally underassessed. Many public spirited assessors attempt to keep assessments low in the belief that the possibility of a high tax rate will make taxpayers careful in voting appropriations at the annual town meeting. The average property owner compares his tax rate with that of a neighboring town instead of comparing his taxes with the taxes on similar property in the other town. Granted that high tax rates resulting from low assessments do effect a reduction in expenditures, the results do not excuse illegal valuations.

Underassessment is common also in towns where the total assessed valuation is low, since state aid for schools and roads is made on the basis of equalized assessed valuation and local expenditures. By means of a high tax rate and low valuations, some towns have been able to obtain more state money than they would otherwise have received. In this case, underassessment benefits one town at the expense of many others.

A third important cause of intentional underassessment is the desire to keep state and county taxes low. These taxes are levied against the town in proportion to its assessed valuation, and while attempts have been made by the state authorities to equalize valuations where a town's valuation was obviously too low, such equalization has failed to remedy the situation.

Property of relatively low value is generally assessed below its fair value, especially when the owner is in poor circumstances, as is often the case. Other investigations have shown that this situation is common to other states.

Similarly, large properties are commonly undervalued. The amount of tax to be paid rather than the actual value of the property assessed seems to be the determining factor in such cases, particularly in small towns where there are few large taxpayers. Such undervaluation may not be intentional; it is often caused by the difficulty of applying unbiased judgment to assessments considerably above the average. However, most cases of such personal discrimination are intentional, especially where a few individuals pay a substantial part of the town taxes or have done a great deal to help the town. This type of discrimination is usually justified by the assessors on the ground that it is better to collect some taxes than to lose them altogether by causing the departure of the wealthy taxpayer to some other town. Such concessions amount to partial tax exemption and where granted to wealthy taxpayers are usually made for the same purpose that Western and Southern towns grant tax exemption to new industries. It is assumed that the benefit to the town offsets the loss in taxes.

Intentional discrimination in assessing the property of non-resident owners is common. Assessors often place low valuations on the cottages or remodelled farmhouses of summer residents in order to encourage further development. In other cases, assessors regard non-resident property owners as fair prey and assess their property proportionally higher than similar property owned locally. Many assessors admit this to be a common practice.

The conclusion should not be drawn from the preceding discussion that most underassessment is intentional. It is true that there is a certain amount of carelessness in assessment, but most assessors are doing the best they can under existing conditions. Fair assessment calls for skilled appraisal, and it can not be expected that assessors who spend only a short time each year at their duties, and who are elected for no more reason than that they are well-known and respected citizens, can perform their duties in expert fashion.

RELATION OF TAXES TO INCOME.

Farm Taxes and Farm Income. (6)

It has been stated previously that the underlying assumption of our general property tax system is the ability to pay as measured by the value of property owned. Taxes must be paid out of income, and if income is not in proportion to the value of the property, then the above assumption is unsound. The property tax assumes that all assessed property is annually and uniformly productive, but obviously this is not the case. Farm property varies greatly in productivity from year to year and the element of risk in farming is greater than in almost any other business. Since property values do not fluctuate with the income from that property, particularly in the case of real estate, it follows that a tax on property value may be unfair in any given year. This is especially true where real estate values are based upon considerations other than productive capacity. The ratio of taxes to income evidently will vary from farm to farm within each town, and from town to town and from season to season. The following tables show the relation between taxes paid and farm income. Farm income may be defined as that part of the farm receipts remaining after paying all expenses connected with the farm operations together with necessary allowances to cover depreciation of farm buildings and equipment and unpaid family labor. It is not the same as net profits as defined for the Federal income tax. Farm income figures are not comparable with corporation income data discussed later because farm income includes wages of the operator as well as any returns for management. Corporation incomes are, of course, computed after deducting these items.

The relation between farm income and taxes is useful in measuring differences between different farming areas, and in comparing the situation in the same area over several years, as in Table 14.

TABLE 13.—Relation of Taxes to Farm Income,[a] 1922-1923

Town	Number of Farms	Farm Income before Deducting Taxes	Taxes	*Ratio of Taxes to Farm Income (Per cent)*
1922				
Heath	24	$ 665	$ 111	*16.74*
Granville	23	1370	109	*7.96*
Ashfield	19	1294	139	*10.74*
Shelburne	27	928	179	*19.26*
Average	**93**	**1045**	**136**	**13.01**
1923				
Hancock	23	1399	106	*7.58*
Heath	26	1022	110	*10.73*
Shelburne	23	1798	180	*10.01*
Average	**72**	**1390**	**131**	**9.43**
2-year Average	**165**	**1195**	**134**	**11.21**

[a] Farm income includes returns to the operator for wages and management, and the interest on his investment.

It is the customary practice to include taxes as one item of farm expense in computing farm income. However, for purposes of determining the relation between income and taxes, the income figures have been computed before taxes were paid. On this basis taxes took 13 per cent of the farm income of the 227 farms considered in 1922. The percentage varied from 8 per cent in Granville to 19 per cent in Shelburne. In 1923, a better crop year, taxes amounted to less than 10 per cent of the farm income, and the average for the two years was about 11 per cent, which compares favorably with other sections of the country. This comparison is shown by Table 15.

The percentage of farm income going to taxes in Massachusetts in 1923 was more than 5 per cent below the average for the United States and more than 3 per cent below the average for the North Atlantic states. Data for one year are not conclusive, but serve to show existing differences at a given time. In a different season the situation might be reversed.

Table 14 shows the relation between farm income and taxes in three towns for the years 1920-1923. The four-year average for all farms was 13.69 per cent of income going to taxes. There was considerable difference between

TABLE 14.—Relation of Taxes to Farm Income,[a] 1920-1923

	Year	Littleton	Boxboro	Sheffield	Total
Number of farms	1920	62	41	40	**143**
	1921	59	39	47	**145**
	1922	48	38	48	**134**
	1923	47	36	52	**135**
	Average	**54**	**38**	**47**	**139**
Average farm income before deducting taxes	1920	$1634	$1202	$1105	**$1362**
	1921	716	331	1066	**728**
	1922	2007	882	1104	**1365**
	1923	2381	1460	1634	**1848**
	Average	**1629**	**965**	**1242**	**1315**
Average taxes	1920	$ 255	$ 141	$ 120	**$ 185**
	1921	245	125	119	**172**
	1922	301	115	112	**181**
	1923	182	140	123	**183**
	Average	**267**	**130**	**119**	**180**
Ratio of taxes to farm income (per cent)	1920	*15.61*	*11.73*	*10.86*	**13.58**
	1921	*34.22*	*37.76*	*11.16*	**23.63**
	1922	*15.01*	*12.99*	*10.18*	**13.26**
	1923	*11.84*	*9.58*	*7.52*	**9.90**
	Average	**16.39**	**13.47**	**9.58**	**13.69**

[a] Farm income includes returns to the operator for wages and management, and the interest on his investment.

years, the average percentages varying from less than 10 per cent in 1923 to nearly 24 per cent in 1921. The differences between towns also illustrate the effect of different types of farming on the ratio of taxes to income. The year 1921 was a poor fruit year for Littleton and Boxboro, farm incomes were low, and consequently taxes took over one-third of income. Sheffield is a dairy town and there was only a slight increase in the percentage of farm income going to taxes in 1921.

TABLE 15.—Relation of Farm Taxes to Farm Income[a] for Selected Farms in the United States, by Geographic Divisions, 1923 and 1924

	Number of Reports		Farm Income[a] (before deducting taxes)		Taxes		*Relation of Taxes to Farm Income (per cent)*	
	1923	1924	1923	1924	1923	1924	1923	1924
United States	16,183	15,103	$1,210	$1,397	$190	$192	*15.7*	*13.7*
North Atlantic	1,800	1,761	1,230	1,189	160	167	*13.0*	*14.1*
South Atlantic	2,131	1.990	850	778	110	122	*12 9*	*15.7*
East North Central	3,395	2,808	1,250	1,385	220	230	*17.6*	*16.6*
West North Central	3,817	3,398	1,350	1,893	240	239	*17.8*	*12.6*
South Central	3,320	3,412	1,030	1,197	140	138	*13.6*	*11.5*
Western	1,720	1,734	1,580	1 760	270	254	*17.1*	*14 4*

U. S. D. A. Yearbook, 1924, Page 268.

[a] "Farm income" represents net business receipts, plus or minus change in inventories for the year. Farm income is not the same thing as reported under the provisions of the Federal income tax law.

The rent paid for the use of a farm is a good measure of income, but there is very little tenancy in Massachusetts and no data are available on the relation of rents to taxes. Tenancy as it is found in the West and South is practically unknown, but there is some cash renting of tobacco land in the Connecticut Valley. This land varies in sale value from $150 to $600 per acre. A conservative average value for the section is $300 per acre at the present time. For tax purposes this land is assessed at about $150 per acre. Land of unusual fertility or site value is assessed higher. The cash rental of tobacco land varies with the season and the value of the land, but a rental of $50 per acre has been asked for average land with tobacco sheds, until the 1926 season. The average assessed value of land and sheds is not more than $300 per acre, which gives a tax of $9.00 per acre with a tax rate of $30.00 per thousand. Taxes therefore take 18 per cent of the rental under these circumstances. With the low rates prevailing in 1926, taxes of course take a larger percentage.

No other type of land is rented to any extent. Onion land is rented on shares, but income from this crop fluctuates so much from season to season that it is difficult to draw conclusions. The tax per acre on onion land is about the same as on tobacco land. The rent per acre normally averages higher on a share basis so that taxes should take a lower percentage of income, but poor returns during the past few years have probably reversed the situation.

It is a common practice to rent pasture but there is no common standard of value. Pasture land rents anywhere from 25 cents to more than $1.00 per acre. In the central and western parts of the state pasture land is assessed at from $15 to $20 per acre. Taking the higher value at a rate of $28.53, the average 1925 tax rate for the state, the tax per year on such land was 57 cents per acre. It seems probable that a great deal of rented pasture does not pay the taxes.

The tax per acre is not a good measure of farm taxes in this state, due to the small number of acres of productive land per farm. In comparing taxes with farm income, it should be remembered that a considerable portion of the farm tax is paid on unproductive scrub, brush, mountain or other waste land. The following table shows the variation in taxes per acre of crop land and all land in farms, by towns, the assumption in the first case being that the entire farm tax is borne by the productive land. The averages for crop land are based on land in crops and hay land but do not include pasture. The tax figures includes all taxes paid for the farm.

TABLE 16.—Taxes per Total Acres in Farms and per Crop Acre, 1922

Town	Number of Farms	Total Acres	Crop Acres	Taxes	Tax per Total Acre	Tax per Crop Acre
Sheffield	48	8,915	3,059	$5,397	$ .72	$1.76
Heath	24	3,862	854	2,671	.69	3.13
Granville	23	2,932	597	2,512	.86	4.21
Ashfield	19	3,113	490	2,641	.85	5.39
Shelburne	27	5,434	998	4,825	.89	4.83
Boxboro	38	3,527	1,244	4,356	1.23	3.50
Littleton	48	5,385	1,888	14,462	2.69	7.65
Total	**227**	**33,168**	**9,130**	**36,864**	**1.11**	**4.05**

Another fact should be considered in comparing taxes with income for the farms under discussion. Many of the farm owners, especially in the western part of the state, derive a considerable part of their cash income from outside work, away from their own farms. Income from outside sources can not logically be included in income from the farm. Accordingly the income from outside sources was subtracted from the farm income in order to show the relation between taxes and the actual income from the farm business. On this basis, taxes equalled 19.2 per cent of the corrected farm income of 227 farms in 1922, while in two towns in the western part of the state taxes took over 40 per cent. Individual farms in several towns did not show a net cash income large enough to pay taxes. This fact supports the statement often made by bank appraisers that taxes are larger than the fair rental for many farms. However, it must be remembered that the farm furnished a dwelling, some fuel, and a considerable quantity of food for the family. In spite of the fact that assessed values are low in proportion to actual values, many farms are not making interest and taxes. This means that reported values are probably too high and in many cases the assessor is closer to the actual value than the owner, at least closer to the productive value for farming purposes.

The Relation Between Corporation Taxes and Income.

It has been pointed out that farm property is assessed relatively lower than other property and it remains to be discovered whether there is a corresponding difference in the relation between income and taxes. Fortunately, corporation data are available from which rough comparisons may be made. In 1925 the Commissioner of Corporations and Taxation reported for the first time the total net income chargeable to Massachusetts received by domestic and out-of-state business corporations operating in the state. The total net income reported was $255,397,770. Taxes paid by business corporations during 1925 were as follows:

Total net excise tax levied	$13,384,000
Property taxes paid, based on an estimate of an assessed valuation of 80% of $1,250,000,000 at state rate of $28.53 per $1000	28,530,000
Total Massachusetts Taxes	41,914,000
Net income from business in the state	255,397,770
Income before deducting property taxes	283,927,770
Per cent of income taken for Massachusetts taxes	*14.76*

In addition to the excise and property taxes collected in Massachusetts, the Federal government imposed a tax of 12½ per cent upon the net income after allowing for local and excise taxes already paid. The total taxes of corporations doing business in Massachusetts in 1925, therefore, amounted to 26 per cent of their net income before deducting taxes.

No data are available on incomes of business corporations for earlier years, but from statistics of public utility companies it is apparent that the percentage of income going to taxes has been increasing. The percentage of net income going to taxes, before making deductions of taxes, interest, dividends, etc., is shown in the following summary:

	1915	1920	1923	1924	1925
Gas companies	18.55	22.35	35.95	38.91	37.97
Electric companies	21.44	21.67	28.60	29.36	30.28
Railroads	——	16.01	105.08	49.70	——
Street railways	——	12.94	32.37	30.67	——

These figures include Federal corporation tax payments and are comparable with the 26 per cent of net income which business corporations paid as taxes. The high percentages of income going to taxes for gas and electric companies are due partly to the large number of companies showing either no profits or small profits. Companies declaring dividends averaged about 10 per cent on outstanding stock. Figures compiled from reports of nine of the larger gas and electric companies in good financial condition, indicate that taxes took 35.5 per cent of the net income before deducting taxes in 1925. Both steam and electric transportation companies improved their earnings in 1925 with a consequent reduction of the percentage of earnings paid for taxes.

There is objection to comparing the preceding figures with those for farms, due to differences in accounting methods. Corporation data are based on accurate cost accounts while farm figures are rough estimates and make no allowance for wages of the farmer. All available information indicates that, if the same accounting methods were used in both cases, at least 50 per cent of the net income from the farm is required to pay the yearly taxes.

Taxation of Farm Corporations. (7)

A comparison of farming corporations with other business corporations is a better measure of the comparative tax burdens. Reports of the Bureau of Internal Revenue show the relation between net profits as defined for purposes of Federal taxation and taxes paid. Net profits as used here are not comparable with net income in the previous discussion. Taxes have been added to net profits in order to obtain a figure for net profits before taxes were paid. Figures are not available for Massachusetts, but on the above basis farming corporations of the United States paid over 65 per cent of net profits for state and local taxes in 1922, as compared with 20 per cent for non-agricultural corporations.[6] On the same basis, over 85 per cent of net profits of farming corporations was required to pay total Federal, state and local taxes. Recent information[7] shows that agricultural corporations were taxed more heavily than other corporations in 1924, both as to the ratio of total taxes to net profits and the ratio of local taxes to net profits. Total taxes required 98 per cent of net profits of agricultural corporations in 1924. The average for all other corporations was less than 30 per cent. One reason for the wide difference is that the agricultural corporation has most of its capital invested in real estate, and hence taxes do not fluctuate with income. Taxes paid by mining corporations take a large percentage of net profits for the same reason.

Farm Taxes and Net Profits.

The relation between taxes and net profits as defined above for the individual farmer is shown by an analysis of 69,601 income tax returns for individual farms in 1923, recently published by the Federal Bureau of Internal Revenue.[8] According to these figures, state and local taxes took an average of 38.4 per cent of net profits before taxes were paid. Only 457 returns were tabulated from Massachusetts out of which 213 reported a net loss. The average net loss per farm for the 457 farms was about $550 before paying taxes, and nearly $900 after state and local taxes were paid. The average for the United States based on 69,601 returns was a net profit of more than $1000 per farm before paying taxes, and of over $600 per farm after taxes were paid. The 244 Massachusetts farmers reporting a net profit paid 13.73 per cent of net profits for state and local taxes.

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[6] United States Department of Agriculture Yearbook, 1924, p. 269, based on Internal Revenue returns.

[7] Press release of the Michigan Agricultural Experiment Station, November 11, 1926. Based on Statistics of Income, U. S. Bureau of Internal Revenue.

Taxation of Savings Banks.

Savings banks are more fortunate than other types of corporations in that taxes usually take a smaller percentage of their income. Savings banks are taxed one-half of one per cent on their average savings deposits, less certain exemptions. The effect of the exemptions has been to reduce the actual taxes collected even with increasing deposits. Since 1921 deposits have increased 29.95 per cent while taxes on deposits have dropped 2.66 per cent. In 1921, 69.9 per cent of the deposits were exempt; in 1925 exemptions had increased to 77.49 per cent. Apparently savings banks are investing their deposits in exempt property as rapidly as possible. In 1925 a tax of one-half of one per cent on total deposits would have returned over $8,000,000 in taxes, whereas the actual tax amounted to only $1,843,000. If this is computed on an income basis, savings banks paid 2¼ per cent of their income as state taxes, provided the banks earned 5 per cent on their deposits. Exemptions have reduced taxes from $5.00 per $1000 deposits to $1.12 per $1000.

Savings banks are subject to local taxation on their real estate. In 1925 the value of real estate used for banking purposes amounted to $19,792,000. Assessing this amount at the average rate of $28.53, giving property taxes amounting to $564,665, or 34.48 cents per $1000 of deposits. Adding this amount to the previous tax gives a total tax of $1.47 per $1000 of deposits. With earnings at $50 per $1000 all taxes take 2.94 per cent of the income. Massachusetts savings banks pay no Federal income tax, because they are mutual associations. Consequently the above taxes represent total tax payments and must be compared with the payment of 26 per cent of the income of business corporations. There is one difference in that patrons of savings banks must pay the Federal Income tax on their interest received provided their income is above the legal minimum, while personal income from business corporations is not subject to the normal Federal income tax.

At the present time over 57 per cent of the total savings bank deposits are loaned on real estate taxable in Massachusetts, and according to law such loans are exempt from all taxes. In buying real estate for $10,000 on which the savings bank advances 60 per cent or $6,000, the buyer pays local taxes at the rate of nearly 3 per cent *on the entire assessed value.* The legal basis for exempting bank deposits is that in such cases the property is taxed locally, and if the bank deposits were taxed it would be double taxation. This exemption is a wide departure from our underlying principle that taxes should be levied according to ability to pay as measured either by value of property or by income. On either basis the savings bank deposits are undertaxed. The savings bank pays no taxes either on local real estate loans or on the income from property loans. Consequently, savings bank deposits practically escape all taxation in direct violation of a fundamental principle of tax justice.

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[8] Statistics of Income, 1924.

It is not believed that savings bank deposits should be taxed at local rates, especially where most of the deposits are loaned on local real estate, but such deposits should not escape taxation entirely. Since interest rates are limited by law, it is only fair to tax savings deposits in real estate loans at a low rate, and the legal rate of one-half of one per cent is fair. It taxes property not otherwise reached and does not place an unfair tax burden on savings deposits. The real estate exemption should be removed.

Taxation of National Banks.

National banks in Massachusetts were formerly taxed upon the value of their shares at the local rate in the city or town where located. This method was declared illegal by the United States Supreme Court, and since 1923 national banks have been taxed either upon share value or upon net income, according to choice. The effect of this change has been to reduce national bank taxes paid to the state by more than 60 per cent. In 1925 only 38 banks were taxed upon share value, while 125 elected to be taxed upon income.

The ratio of total taxes paid by Massachusetts national banks to net additions to profits before deducting taxes has declined each year for the past five years. The comparison of Massachusetts banks with the average for the country follows.

Ratio of Total Taxes to Net Additions to Profits before Deducting Taxes.[a]

Year Ending June 30	Massachusetts Per Cent	United States Per cent
1922	45.31	30.17
1923	31.84	24.88
1924	25.65	25.32
1925	20.67	22.71
1926	15.73	21.58

[a] Adapted from annual reports of the Comptroller of the Currency.

The ratio of taxes to profits before deducting taxes has declined much more rapidly in Massachusetts than for the country as a whole, due to the change in the law mentioned above.

Available figures indicate that in proportion to income national banks in Massachusetts pay lower state and local taxes than other business corporations except savings banks.

Summary.

It has been shown that property of all kinds is generally undervalued for assessment purposes. There are wide differences in the ratio of actual to assessed values between farms in the same town, between farm and city property, and between towns. Farm real estate appears to be assessed at a lower percentage of value than other kinds of property. If value of property owned reflects ability to pay taxes, farmers appear to be in an advantageous position.

However, farm values are affected by factors other than earning power, and income is a better measure of ability to pay. Farmers pay proportionally more of their income for taxes than other business or professional groups. Even though farm property is underassessed, farmers are still at a comparative disadvantage with other industries.

The essential difficulty lies in our general property tax system, which attempts to measure the ability to pay taxes by the value of property owned. Inasmuch as this system is firmly entrenched and there appears to be little likelihood of change for some years, improvements in the present situation can be made only through improving assessment practice.

SUGGESTIONS FOR IMPROVING ASSESSED VALUATIONS.

Since earnings of real estate are a better measure of present value than selling price, it is suggested that assessors give first consideration to the productivity of property in determining fair valuations. Experienced assessors are necessary and the term of office of the assessor should be lengthened in order to give local communities the benefits of the experience secured during the first few years of office.

It has been the experience of states in New England and other parts of the country that the town or township is too small a unit for efficient assessment without adequate control from county, district or state officials. Local assessments would be improved if the tax commissioner were given power to equalize them where necessary. One possible solution is the establishment of assessment districts, whereby a group of small towns might unite to employ a full-time capable assessor who would either work with or supplant the local boards. A tax expert familiar with farm valuations and employed under state authority would also be of great service in working with assessors in rural towns.

Assessment maps on a scale large enough to show the location, size and assessed valuation of each piece of property are a valuable aid in eliminating inequalities in assessment as well as discovering untaxed property.

It is suggested that the annual meetings of the several county associations of assessors be expanded into county tax conferences for the purpose of considering local assessment problems in detail. One phase of such a conference might be a demonstration of methods of appraisal used by professional appraisers for different kinds of property. The exchange of experiences, together with the educational value of a thorough analysis of one or more local problems at each annual meeting, should do much to promote uniformity in assessment practice.

APPENDIX.

1. (p. 87) The ratio of value of exempt livestock and farm implements to total farm wealth was approximately the same as the ratio of total exempt property to total wealth.

2. (p. 89) The estimates were arrived at by making the following deductions:

Real Estate	
Small farms which were really country homes for city workers	$ 12,730,000
Overestimation to census enumerator	24,187,000
Undervaluation by assessors	87,074,000
Total	123,991,000
Livestock	
Exempt young livestock, 10 per cent of total	2,176,000
Exempt poultry, $15 per farm for 30,000 farms	450,000
Undervaluation by assessors, 25 per cent of remainder	4,783,000
Total	7,409,000
Implements and Machinery	
All farm tools are exempt. The estimate covers only tractors and taxable machinery.	

3. (p. 89) Value of farm motor vehicles is based on estimates of 24,000 passenger cars and 8,000 trucks. It is assumed that motor vehicles on farms have increased in proportion to total registration since 1920.

4. (p. 89) Registration fees at 1926 rates averaged at least $11 per passenger car and $25 per truck.

5. (p. 90) The 1925 census reported 33,000 farms, the 1920 census only 32,000. The increase was apparently in the small farms which were residences of city workers

6. (p. 111) The number of farms considered is too small for a fair sample of the state, especially since some of the more prosperous types of farming were not included in the surveys. However, the relation between income and taxes on the limited number of farms is about the same as for the larger number covered by the United States Department of Agriculture. The towns included are typical of their section and the comparative figures for two or more years illustrate local changes in both income and taxes.

7. (p. 116) Farming corporations include those engaged in farming and related industries such as forestry, fishing, and ice harvesting. More than 80 per cent of those reporting a net income are farming corporations, however. Such corporations are scattered and of little importance to the industry, and the relation between taxes and profits may not be typical of the industry.

Publication of this Document approved by the Commission on
Administration and Finance.

5 M. 4-'27. Order 8638

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 236 MAY, 1927

THE MILK SUPPLY OF MASSACHUSETTS

By R. J. McFALL

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I. Local Production and Imports.

II. Consumption and Sources of Supply in Springfield and Vicinity.

III. Milk Production and Shipped-in Feed.

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AGRICULTURAL EXPERIMENT STATION
AMHERST, MASS.

THE MILK SUPPLY OF MASSACHUSETTS

By R. J. McFall

I. LOCAL PRODUCTION AND IMPORTS

The State of Massachusetts draws heavily upon outside sources of milk, the locally produced supply being inadequate to meet the demand. For some decades the city of Boston has been obliged to import milk from other states. At the present time fluid milk is shipped into the state from New Hampshire, Connecticut, Maine, Vermont, New York, and to a limited extent from Canada.

Closely connected with the Massachusetts milk market is that of Providence, Rhode Island, which draws supplies from the northern New England states in transit through Massachusetts, and also from the nearby Massachusetts farms.

Connecticut produces more milk than it uses and draws no milk from the north. A small amount of milk is shipped from Massachusetts farms to Hartford and sweet cream is shipped from the northern states to Connecticut during the summer months. Northeastern Connecticut ships some milk to Boston and Providence, and Springfield draws some milk from nearby Connecticut towns.

Southwestern Berkshire County in Massachusetts and the western valleys of Connecticut, being served by rail lines converging to New York City, ship milk to the latter market rather than to the industrial centers of New England. Considerable milk is also shipped to New York from the western counties in Vermont. The shipments to that market from New England farms nearly offset the shipments to Boston and Springfield from farms in New York State near rail lines converging to the latter cities. Thus the milk production of New England is sufficient for its own fluid milk markets and the shipments from and to New York State are based upon the convenience or economy of transportation.

By far the greater portion of the large production of milk in Massachusetts is consumed in the smaller centers of population. The country, the villages and the small towns are supplied almost entirely from local production. The larger cities, particularly in the Metropolitan district, cannot find sufficient local supplies and they afford the market for the milk from the north. Some of the cities near the northern boundary of the state bring in part of their milk by auto truck, but most of the shipments come by rail.

Through the courtesy of the Boston and Maine Railroad Company, it has been possible to ascertain the exact quantity of milk and cream shipped into the state by rail during March, 1926, and September, 1925. About three-fifths of these quantities went to Metropolitan Boston. Since the Department of Public Utilities has complete data on monthly rail shipments to Boston, it has been possible to make a close estimate of the total annual rail shipments into the state.

Shipments by truck from Vermont and New Hampshire to the cities in northern Massachusetts have been learned through the courtesy of the milk inspectors of those cities. The shipments to New York City from Berkshire County were obtained through the cooperation of the Agricultural Agent in that county.

TABLE 1.—Annual Quantity of Milk and Cream Used in Massachusetts (Quarts)

	Milk		Cream		Total Milk Equivalent*		Per cent of Total		
							Milk	Cream	Milk and Cream
State production available for human use (95% of total production)		**404,275,814**		....		**404,275,814**	**59.4**	.....	**37.3**
Shipped in from the North:									
By rail	284,441,161		41,000,333		694,444,491				
Transit to Rhode Island	*4,880,050*		*704,500*		*11,925,050*				
Net by rail from North		279,561,111		40,295,833		682,519,441	41.1	99.96	63.0
Net by truck from North		8,677,875		....		8,677,875	1.3	.....	.8
Shipped in from Connecticut	5,579,127		11,002		5,689,147				
Shipped out to Connecticut	*625,930*				*625,930*				
Net from Connecticut		4,953,197		11,002		5,063,217	.7	.03	.5
Net Imports from the North and Connecticut		**293,192,183**		**40,306,835**		**696,260,533**	**43.1**	**99.99**	**64.3**
Shipped in from Rhode Island	17,929		5,093		68,859				
Shipped out to Rhode Island	*4,741,350*				*4,741,350*				
Net to Rhode Island		*4,723,421*		....		*4,672,491*	*.7*		*.4*
Net from Rhode Island				5,093				.01	
Net shipped out to New York†		*12,439,200*		....		*12,439,200*	*1.8*	.....	*1.2*
Net Imports from Rhode Island				**5,093**				**.01**	
Net Exports to Rhode Island and New York		*17,162,621*		....		*17,111,691*	*2.5*		*1.6*
Total Available for Use in Massachusetts		**680,305,376**		**40,311,928**		**1,083,424,656**	**100.0**	**100.0**	**100.0**

* Total Milk Equivalent = number of quarts of milk + ten times the number of quarts of cream.

† Milk shipped in from New York is included in the item "Shipped in from the North by rail."

Table 1 brings together all these data into a composite picture of the milk supplies of Massachusetts and its transit trade for a whole year. The figures are for the year 1926, excepting those for shipments to New York and the state production, these being for the year 1925.[1] The production estimate is that of the New England Crop Reporting Service and is materially larger than that of the census of 1925. This latter includes only the production of cows kept on farms and amounts to 346,300,332 quarts. The use of this figure would reduce the estimate of the total available supplies by 75,000,000 quarts. This difference would amount to about .05 quarts per capita per day. Either estimate of production requires a reduction of 5 per cent as a minimum for wastage and feeding on farms, not more than 95 per cent of the production being available for human use.

Much of the total supply of cream and some of the milk is used for making ice-cream. Moreover, much of the locally produced milk, especially in the summer, is used for other purposes than fluid milk consumption. According to the census data approximately 15,000,000 quarts of milk went into farm butter and about 25,000,000 quarts formed the basis for the farm sale of butter-fat and cream. Thus about 40,000,000 quarts were skimmed or separated on the farms. The amount of fluid milk used for commercial ice-cream and baking is also unknown. Making the conservative assumption that an amount equal to only 25 per cent of the local production went into all these so-called "surplus" uses, fluid milk available for consumption could hardly be greater than .40 quarts per capita per day and might easily be lower than .35 quarts on the basis of the production estimates of the New England Crop Reporting Service. On the basis of the census estimates of milk production a reduction of .05 quarts would be made.

It is fruitless to attempt to estimate the per capita consumption of cream. An unknown amount of the fluid milk shown in the table was made into cream. A large part of the cream went into the ice-cream trade which also uses large quantities of sweet butter and condensed milk.

The quantities of milk and cream shipped into the state are much more definite than the uses to which the milk is put after it arrives, or than the amount of the local production. Table 1 shows these requirements to a high degree of accuracy for the whole year. However, the requirements vary within the year. Table 2 shows the estimated daily requirements of Massachusetts and Rhode Island for northern milk in the four sample months of January, May, July and October.

TABLE 2.—Estimated Daily Requirements of Northern Milk by Massachusetts and Rhode Island. (*Quarts*)

	Fluid Milk	Cream	Total in Milk Equivalent *a*
January	732,845	75,070	1,483,545
May	779,369	149,286	2,272,229
July	846,310	166,248	2,508,790
October	804,930	92,447	1,729,400

a Total in Milk Equivalent=number of quarts of milk+ten times the number of quarts of cream.

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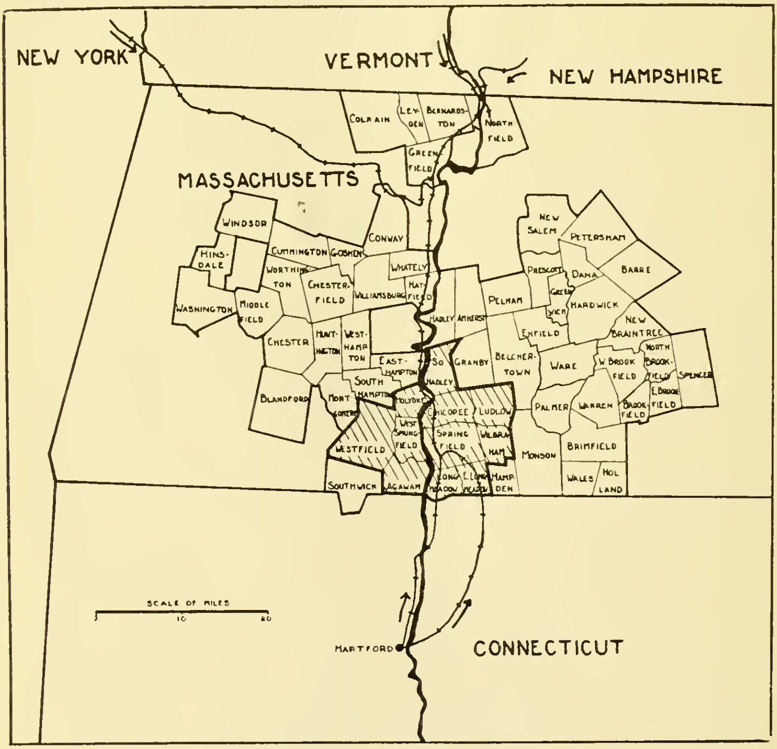
[1] Preliminary estimates of the New England Crop Reporting Service indicate a production for 1926 about one per cent greater than for 1925.

II. CONSUMPTION AND SOURCES OF SUPPLY IN SPRINGFIELD AND VICINITY

In order to obtain some dependable data on the consumption of milk by the urban population of Massachusetts a study was made of a selected urban district typical of many in the state, where it was possible to collect reliable figures on milk receipts and retail distribution. Springfield, Massachusetts was the area chosen for study, and enough of the surrounding cities and towns were added to include all the regular commuters and all the outlying areas served by the retail distributors of these centers. The accompanying map shows the boundaries of the area and the cities and towns included. It contains about 252 square miles and a population in 1925 of 309,950. The cities and towns in the area are Springfield, West Springfield, Longmeadow, East Longmeadow, Wilbraham, Chicopee, Agawam, Westfield, Holyoke, Ludlow and South Hadley.

Sources of Milk entering the Springfield Area.


NEW YORK
VERMONT
NEW HAMPSHIRE
MASSACHUSETTS
COLRAIN
LEYDEN
BERNARDSTON
NORTHFIELD
GREENFIELD
WINDSOR
CONWAY
HINSDALE
CUMMINGTON
GOSHEN
WORTHINGTON
WHATELY
CHESTERFIELD
WILLIAMSBURG
HATFIELD
WASHINGTON
MIDDLEFIELD
NEW SALEM
PETERSHAM
PRESCOTT
DANA
BARRE
GREENWICH
HARDWICK
PELHAM
HADLEY
AMHERST
ENFIELD
NEW BRAINTREE
CHESTER
HUNTINGTON
WESTHAMPTON
EASTHAMPTON
SO HADLEY
GRANBY
BELCHERTOWN
WARE
W BROOKFIELD
NORTH BROOKFIELD
SPENCER
E BROOKFIELD
BROOKFIELD
SOUTHAMPTON
BLANDFORD
MONTGOMERY
HOLYOKE
CHICOPEE
LUDLOW
PALMER
WARREN
WEST SPRINGFIELD
SPRINGFIELD
WILBRAHAM
WESTFIELD
MONSON
BRIMFIELD
SOUTHWICK
AGAWAM
LONGMEADOW
E LONGMEADOW
HAMPDEN
WALES
HOLLAND
SCALE OF MILES
5
10
20
HARTFORD
CONNECTICUT

It has been customary to compute the average milk consumption in our cities by dividing the number of quarts reported as sold by the dealers in each city by the number of inhabitants as reported by the census. This basis of estimation has left much to be desired from the standpoint of statistical exactness.

Aside from the inaccuracy of the sales data reported by the dealers, two serious statistical errors are involved in this method of computation, each error involving an over-estimate of the average per capita consumption. Dealers customarily sell milk in the towns or cities surrounding the city in which their principal business is located and frequently report their total sales as pertaining entirely to the central city. This inflates the figures on milk sold within the city limits. Moreover, the milk sold in any large city is consumed by a population much larger than those counted by the census as residents. The number of those who reside outside of the city, but eat one or more meals there, regularly or occasionally, is very large, especially in the case of the chief cities.

In this study every effort was made to avoid these inaccuracies. The area was carefully chosen and the data on receipts and consumption were carefully scrutinized. It was assumed, however, that the number of visitors entering the area was not greater than the number leaving it during the year. For this reason abnormally large milk handlings of the week of the Eastern States Exposition were excluded.

With the assistance of the milk inspectors in these markets the amount of cream for the fluid cream trade and the amount of milk handled by each dealer was ascertained. The sources of this milk and cream were found to be three: that produced in the local area; that which is secured from elsewhere in the state; and that which is secured outside the state. Special statements based directly upon their records were secured from all the large dealers, and care was taken to avoid duplication of data when milk was sold at wholesale.

Data were obtained for conditions as they existed in the late fall of 1926 during which period practically no dealer had any surplus and it was certain that only small and measurable quantities of local milk failed to go into fluid milk trade.

The milk and cream available for consumption included the local production as well as the supplies shipped in from the outside. Local production was estimated for October by multiplying the total number of cows in the area, as shown by the tax assessors' data for 1925, by the average milk production per cow in Hampden County, as estimated by the New England Crop Reporting Service for October 1925. From this five per cent was subtracted to cover wastage and use in feeding on the farms. The result gave the daily supply available in October. To obtain a more accurate estimate of the daily average for the year, data were secured from the leading dealers showing the sales in each month of the year, and this October supply was multiplied by the ratio between the average for all months and the October sales. The resulting average was then divided by the population of the area as shown by the state census for 1925.

Data for fluid cream consumption were carefully secured in addition to the data for milk. Such estimates as have been available hitherto for cream consumption in Massachusetts appear to be even less exact than those for milk. Part of the supply counted has been used for manufacturing into ice-cream and a considerable portion of this product has been shipped to other consuming centers.

In this study the cream included was all used for the fluid cream trade, including the supplies used by restaurants and soda fountains in the form of fresh cream. The small amount sold as "light cream" was converted to the equivalent of 40 per cent or "heavy" cream, which is the ordinary article of commerce in the region. The results show that the average per capita consumption of milk is only .38 quarts a day. This is a smaller quantity than the customary estimates for similar communities.[1] The average consumption of cream is .015 quarts a day. Converted to the basis of the milk required to make the cream, this equals .16 quarts of milk in addition to that consumed as milk. Even the total, .54 quarts of "milk equivalent", is not large and indicates that an increased consumption might be stimulated.

Sources of Supply

The following table shows the sources of milk and cream in the fall months. During the early summer a much larger place would be taken by supplies from the local area and from other Massachusetts sources. During the season of low production, by far the larger part of the cream comes from outside the state and practically none of the milk produced in the local area is made into commercial cream.

Sources of Milk and Cream used in the Springfield Area in the Fall of 1926.
(Quarts per Day)

	Milk		Cream		Total in Milk Equivalent*	
	Quarts	*Per cent*	Quarts	*Per cent*	Quarts	*Per cent*
Local production	38,628	*31.2*	.....	....	38,628	*22.1*
Other parts of Massachusetts	56.872	*46.0*	308	*6.4*	60.157	*34.4*
Other states	28,112	*22.8*	4.477	*93.6*	75,867	*43.5*
Total	**123,612**	*100.0*	**4,785**	*100.0*	**174,652**	*100.0*

* Total in Milk Equivalent = number of quarts of milk + ten times the number of quarts of cream.

It thus appears that this area produces 22.1 per cent of its fluid milk even in seasons of short production, brings in only 43.5 per cent of its supply from other states, and gets the remaining 34.4 per cent from more distant sources within the state. In addition to these supplies for fluid consumption, there is a material supply of milk, cream and ice-cream "mix" coming into the area for the ice-cream trade.

There are six original receivers of supplies from other states. Two of these are cooperative concerns handling, almost entirely, milk produced by members. Two are dealers handling the output of a cooperative creamery in southern Vermont. Of the two other dealers handling out-of-state supplies, one handles but a few hundred quarts and both purchase more milk for fluid consumption within the state than outside of it. Two large dealers handle no regular supplies of milk but that of Massachusetts origin, although their business is large enough to allow car-lot shipments from the north. One of these bought northern milk for a brief period when his Massachusetts patrons signed a contract with a cooperative concern, but is again purchasing only from Massachusetts sources.

The accompanying map shows the origins of supplies entering the Springfield area.

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[1] This estimate is based upon that of the New England Crop Reporting Service for October 1925, for Hampden County, which was the only material available for such a localized study at the time of writing. In the light of preliminary estimates of the same agency for 1926 and the agricultural census of 1925, it appears that there is sufficient indefiniteness in the local production data to give a probable margin of error of +.02 quarts in the total milk consumption. The difference in local production estimates does not affect the estimates for cream consumption which are based almost wholly upon the shipped-in supplies.

III. MILK PRODUCTION AND SHIPPED-IN FEED

The output of milk from the farms of Massachusetts and the other New England states is based only in part upon the product of the native soil. To a very considerable extent it is based upon purchased feeds which are the product of the farming of other regions. To a certain extent, also, these purchased feeds form the basis for improving the fertility of the local soil and make a small contribution to the second-quality meat which is a by-product of the local dairy industry. It is the purpose of this paper to make as close an estimate as the available data permit of the relation of this purchased feed to the food production of the dairy industry.

In one sense all of the milk output from the New England farms is locally-produced food. In the form of milk it is strictly a local product and the feeds brought in from the West would be of little or no value for direct human consumption. Nevertheless, milk coming from a herd fed largely on purchased hay and grain is not as completely the product of local farming as is the milk coming from a pasture section where little or no feed is brought in from the outside. The payment for feed requires a large deduction from the profits in the first case. The milk made by the use of western grain is also partially based upon the product of the soil in other sections of the country, and its flow would be diminished if the supply of outside grain were stopped. Thus part of the local milk production is merely the final stage in a series of operations in food production, the earlier stages of which are conducted elsewhere.

Method of Estimate

Th fairest basis for estimating the proportion of milk production based upon locally-produced feeds, as distinguished from that due to purchased feeds, is the relative nutritive value contained in each of these classes of feeds. Under practical conditions the dairy cow usually gets a fairly well-balanced ration, certainly a mixture of roughage and some form of concentrates. The problem is to find the share which each class of feeds contributes to production in mixed rations as they appear in practice. To this end it is necessary, by some such means as reducing the nutritive value of the feeds to some common denominator and ascertaining the quantity used of each, to determine the ability of each group of feeding stuffs to produce milk.

Several common denominators are used for comparing the nutritive value of different feeds. Recent practice among nutritional chemists gives a leading place to the measure known as the net thermal equivalent. This is comparable to the calorie which is used in measuring the nutritive value of human foods. It takes account, however, of the fact that much of the fiber in animal feed, while having a thermal value, has little energy value for utilization in the bodies of the animals. Only the part of the feed which is actually utilized for production and maintenance is included in the net thermal equivalent.

The net thermal equivalent, accordingly, is used in determining the nutritive value in all feeds whose use is measurable in terms of weight.

This applies to all hay, silage and grain. The feed derived from pastures is not readily measurable in weight. Hence, no formula for its net thermal equivalent per ton can be applied. However, pasturage largely takes the place of hay and silage during certain months of the year, and the proportion of the year during which the cows are on grass is known quite accurately. It is also possible to estimate fairly closely the amount of hay and corn fodder fed to cows during the pasture season. The feed value of the pasture is then taken to bear the proportion to the value of the hay plus silage used in the non-pasture months that the milk actually produced during the pasture season bears to the milk produced during the rest of the year, due allowance being made for the limited use of cut roughage during the pasture months. Uncut green feed, such as aftermath, is thus included with the pasture grass.

Data Available

Data are available through the Statistical Division of the New England Milk Producers Association which show the average amount of hay, silage and grain used throughout the year per hundred pounds of milk, and the relative amount of each kind of grain used both in summer and winter. This information is secured from reports made by dairymen in all sections of New England excepting Rhode Island and western Connecticut. These reports follow field surveys conducted in 1917 by certain war-time public agencies acting in cooperation with the New England agricultural colleges, the results of which were published by the Boston Chamber of Commerce.

The Census supplies data on hay production by counties which afford a good basis for estimating the extent to which certain counties in southern New England depend upon hay brought in from the outside. Observation of the industry shows that in counties in which the total hay production is less than four tons per head of dairy cows, some hay is brought in from other regions. Since such shipments are to but very limited extent made from other parts of the same state, it is assumed that each county which produces less than four tons per head of dairy cows makes up the deficit by shipping in hay from outside of its state.[1] New England as a whole, however, has sufficient hay for her dairy industry and most of the shipments of hay are from the northern to the southern states of this district. Accordingly, in computing the New England average, it is assumed that all the hay used in the dairy industry is home grown.

Data on the proportion of milk produced in each month are now available for each state through the New England Crop Reporting Service. These data are of service in computing the relation of the feed value in the pasturage to the feed value in other roughage.

Process of Estimate

Table 1 shows the pounds of each main class of feeds, except pasturage, used per hundred pounds of milk produced, as an average for each state (except Rhode Island) in the year 1923.

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[1] While this is four tons of hay per cow, it is clear that young stock and horses share in the use of the hay and that each cow consumes a supply of less than four tons.

TABLE 1.—Pounds of Feed used per Hundredweight of Milk Produced, Year's Average, 1923.

Feed	Maine	New Hampshire	Vermont	Massachusetts	Connecticut
Grain	34.0	27.6	19.5	39.3	34.9
Silage	91.4	67.3	68.2	108.8	156.5
Hay	62.1	76.0	100.6	62.5	64.6

Source: New England Milk Producers' Association.

Sample data are available for both winter and summer which show the relative proportion of each kind of concentrated feed used in each of the states. These data have been submitted to the scrutiny of men familiar with the commercial movements of dairy feeds and pronounced to be in reasonable agreement with trade information. Table 2 presents the data in detail, showing the percentage of each kind of feed used and the net thermal equivalent of each per hundredweight of all grain.

In northern New England there is a certain amount of home-grown grain fed to the cows. The list of concentrated feeds in Table 2 shows, however, that nothing other than corn, oats or "provender" can come from home farms. Practically all corn fed to cows is consumed as silage or stover, which latter is classed with hay. Any small use of grain from local corn on a few farms offsets the use of silage on the typical farm. Some oats are grown and either fed direct to cows or exchanged as seed oats with the feed dealers who supply an equivalent amount of ground oats. Even in the case of oats in Maine, however, the grain is shipped in from the outside in large quantities. These northern states, which do produce some coarse grains, feed more of this type of concentrates than the southern states do. It is estimated from this fact and other evidence in Table 2 that 5 per cent of the grain in Maine, 2 per cent in New Hampshire and 1 per cent in Vermont is home grown.

In southern New England little or no home-grown grain is fed except in the form of silage. The corn-and-cob meal fed on a few farms takes the place of silage. Shelled corn and oats from local fields go almost entirely to the hogs or horses.

No direct feeding data being available for Rhode Island, it is estimated that the feeding practice in that state follows the average of its two neighbors, Massachusetts and Connecticut. However, the estimated purchase of hay from the outside is based upon the local shortage as computed from census data. The relation between the feeding value of pasturage and other roughage is also worked out from data applying directly to this state.

Table 3 brings all these data together in summary form and shows the final computations of the percentage relation of home-grown and shipped-in feed to the total. The data for New England as a whole are computed from those of the separate states, assuming that all hay is grown in New England and weighting the averages by the production of milk in each state. Any error arising from the particular samples taken probably underestimates the dependence of Connecticut upon outside feed and overestimates that of Maine and Vermont. The sample should be more accurate for Massachusetts and New Hampshire.

The final computations show that, for New England as a whole, 23.04 per cent of the milk production is based upon outside feed and 76.96 per cent on home-grown supplies; while for Massachusetts the corresponding figures are respectively 30.48 and 69.52 per cent.

TABLE 2.—Percentage of Different Feeds Used in Producing Milk in New England States, and the Net Thermal Equivalent of Each per Hundredweight of All Grain.

Feed	Net Thermal Equivalent Per Cwt.	Maine		New Hampshire		Vermont		Massachusetts		Connecticut	
		Per Cent	Net Thermal Equivalent (Therms)*	*Per Cent*	Net Thermal Equivalent (Therms)*	*Per Cent*	Net Thermal Equivalent (Therms)*	*Per Cent*	Net Thermal Equivalent (Therms)*	*Per Cent*	Net Thermal Equivalent (Therms)*
Corn Meal	85	*12.5*	10.6	*8 75*	7.4	*6.25*	5.3	*5.75*	4.9	*19.75*	16.8
Cottonseed Meal	84	*15.0*	12.6	*9.0*	7.6	*5.0*	4.2	*9.75*	8.2	*6.25*	5.3
Dried Beet Pulp	76	.....	....	.....	....	.....	....	.....	....	*.25*	2
Gluten Feed	81	*9.5*	7 7	*12 75*	10.3	*3.75*	3.0	*10.0*	8.1	*3.5*	2.8
Ground Oats	68	*9 0*	6.1	*6 0*	4.1	*4.75*	3.4	*5.25*	3.6	*4.5*	3.1
Hominy	89	*25*	.2	.....	....	.....	....	*6.25*	5.6	*1.25*	1.1
Linseed Oil Meal	89	*2 25*	2.0	*3 5*	3 1	*2.25*	2.0	*1.75*	1 6	*4.75*	4.2
Stock Feed	66	*1 0*	.7	*6 25*	4.1	*.25*	.2	*5.5*	3.6	*.25*	.2
Wheat Bran	53	*19 25*	10.2	*14 75*	7.8	*6.25*	3.3	*10.25*	5.4	*14.0*	7.4
Wheat Middlings	59	*.75*	.4	*.25*	.1	.....	....	.....	....	*.75*	.4
Wheat Mill Feed	59	*1.0*	.6	*1 25*	.7	*.75*	.4	.....	....	.....	....
Provender	79	*25*	.2	*1 5*	1 2	*3.0*	2.4	.....	....	.....	....
Commercial Mixed Feeds	..†	*29 25*	19.0	*36 0*	24.5	*67.75*	47.4	*45.50*	31.9	*44.75*	31.3
Total		*100.0*	**70 3**	*100 0*	**70 9**	*100.0*	**71 6**	*100 0*	**72 9**	*100 0*	**72 8**

* The therm represents the amount of heat required to raise 1000 kilograms of water 1 degree Centigrade, and is used as a unit of measurement for energy.

† Net Thermal Equivalent for Maine, 65; N. H., 68; Vt., 70; Mass., 70; Conn. 70

SOURCE: NEMPA for feeding rations, using weight of 3 for November feed and 1 for June feed.

TABLE 3.—Feed Units Used per Hundredweight of Milk Produced.

Distinguishing between home-grown and shipped-in feed for each state and all New England.

State and Origin of Feed	Net Thermal Equivalent					Percentage of Total Feed Units
	Grain	Silage	Hay	Pasturage	Total	
	Therms	*Therms*	*Therms*	*Therms*	*Therms*	
Maine						
Home-grown	1.2	14.5	23.6	26.8	**66.1**	*74.43*
Shipped-in	22.7	0.0	0.0	0.0	**22.7**	*25.57*
Total	**23.9**	**14.5**	**23.6**	**26.8**	**88.8**	*100.00*
New Hampshire						
Home-grown	.4	10.7	28.9	23.5	**63.5**	*76.77*
Shipped-in	19.2	0.0	0.0	0.0	**19.2**	*23.23*
Total	**19.6**	**10.7**	**28.9**	**23.5**	**82.7**	*100.00*
Vermont						
Home-grown	.1	10.9	38.2	32.7	**81.9**	*85.55*
Shipped-in	13.9	0.0	0.0	0.0	**13.9**	*14.45*
Total	**14.0**	**10.9**	**38.2**	**32.7**	**95.8**	*100.00*
Massachusetts						
Home-grown	0.0	17.3	22.6	27.8	**67.7**	*69.52*
Shipped-in	28.6	0.0	1.1	0.0	**29.7**	*30.48*
Total	**28.6**	**17.3**	**23.7**	**27.8**	**97.4**	*100.00*
Connecticut						
Home-grown	0.0	21.7	23.9	31.7	**77.3**	*74.77*
Shipped-in	25.4	0.0	.7	0.0	**26.1**	*25.23*
Total	**25.4**	**21.7**	**24.6**	**31.7**	**103.4**	*100.00*
Rhode Island						
Home-grown	0.0	19.5	17.9	27.0	**64.4**	*65.94*
Shipped-in	27.0	0.0	6.3	0.0	**33.3**	*34.06*
Total	**27.0**	**19.5**	**24.2**	**27.0**	**97.7**	*100.00*
New England						
Home-grown	.3	15.0	28.6	29.1	**73.0**	*76.96*
Shipped-in	21.7	0.0	0.0	0.0	**21.7**	*23.04*
Total	**22.0**	**15.0**	**28.6**	**29.1**	**94.7**	*100.00*

It would be worth while at some later date to revise these estimates after securing a greater range of reports than the sample data obtained for other purposes by the New England Milk Producers Association.

Comparisons with Other Dairy Countries

The foregoing conclusions take on greater meaning through comparison with the situation in the animal industries of other countries having highly developed dairying.

The United Kingdom has developed an intensive dairy industry which depends partially upon imported feedstuffs. Sir Thomas Middleton estimates that at the outbreak of the war 340 million out of a total of 1,800 million gallons of milk produced were based upon concentrated feeding stuffs. Of these concentrates approximately 32 per cent were home grown and 68 per cent of foreign origin.[2] Accordingly, about 13 per cent of the British milk supply was based upon imported feeding stuffs.

A committee of Germany's leading scientists, under the chairmanship of Professor Paul Eltzbacher, estimated that just before the war one-half of the German milk production was based upon imported fodder. This conclusion seems untenable in the light of the statistical evidence presented by the same authorities and what they admit, and experience elsewhere shows, of the efficiency of the dairy cow in converting feed into milk. The evidence presented would lead rather to the conclusion that about 30 per cent of Germany's milk was based upon imported feed.[3]

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[2] Middleton, T. H. Food Production in War, pp. 36, 74.

The degree of dependence of the French dairy industry upon outside feed supplies is much less. No data are available distinguishing the feed used by dairy cows from the feed of other animals. However, the very complete data presented by the Inter-Allied Scientific Food Commission, covering all feedstuffs used by the total livestock of the nation in the average pre-war year, show that, on the common denominator of starch equivalents, only about 5 per cent of the total feed supply came from the outside world.[4]

Denmark has probably made more rapid strides in the development of the dairy industry in the last generation than any other nation, and this achievement has been made with the use of a heavy importation of feeding stuffs. Mr. Chris L. Christensen of the United States Department of Agriculture and Professor Larsen of Copenhagen have jointly estimated that approximately 40 per cent of Denmark's feed for her animals comes from other countries.

The Netherlands also take a leading part in the dairy industry and, with a somewhat smaller livestock population than Denmark, normally import more than twice as much feed.[5]

It would appear that the degree of New England's dependence upon outside feedstuffs is not unduly high as compared with the situation in some of the leading dairy nations.

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[3] Eltzbacher, Paul, et al. Die deutsche Volksernahrung und der englische Aushungerungsplan. English translation by Waller, pp. 70, 106, 141.

[4] Commission Scientifique Interalliee du Ravitaillement. Deuxieme Rapport, p. 28.

[5] See data presented in Eltzbacher, op. cit., pp. 13-14, and McFall, R. J. The World's Meat, pp. 238-239.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 237 OCTOBER, 1927

LIMING ONIONS

By J. P. Jones

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MASSACHUSETTS AGRICULTURAL COLLEGE
AMHERST, MASS.

In the summer of 1926 many fields of set onions in the Connecticut Valley onion district were found to be stunted in growth, with tips turning yellow and leaves dying back. Many rather diverse diagnoses of the difficulty were made. An investigation carried on by the Experiment Station, in cooperation with the Hampshire County Extension Service, showed that the trouble was caused by too great acidity of the soil, a condition which can be remedied by the use of lime. This bulletin reports the results of the study, with recommendations of preventive measures.

Requests for bulletins should be addressed to the
AGRICULTURAL EXPERIMENT STATION
AMHERST, MASS.

LIMING ONIONS

By J. P. Jones[1]

In the summer of 1926 many set onions were found to be turning yellow at the tips, with the leaves dying back, and growth stunted. In several cases there was little growth beyond that which would naturally be accounted for by the set itself. So prevalent were these conditions that the County Agent of Hampshire County, Mr. Roland Payne, in cooperation with the Massachusetts Agricultural Experiment Station, made a careful study of 114 onion fields on which sets were growing, located in Hadley, North Hadley, Hatfield and Bradstreet. The fields were selected at random, soil samples taken, and yield records obtained. In the laboratory, soil acidity determinations were made on each of the samples.

Many Onion Soils Too Acid For Best Growth.

There are a number of methods for measuring soil acidity. In the work reported here the Soil-Tex was used for rough estimations in the field; the Wedge Comparator for the more exact laboratory measurements. For both methods the unit of measurement is called pH. (See figure 1). The neutral point is pH-7, and is neither alkaline nor acid but of the same reaction as pure water. Above pH-7 is alkaline and below it acid of varying degrees.

Practically all onion soils are acid and fall within the range indicated in figure 1—pH-4.0 to 7.0. The best onions generally grow in the slightly acid soil, pH-6.0 to 7.0. Those grown on soils with a reaction of pH-5.0 to 6.0 are only fair, while attempts to grow onions on a soil with reaction below pH-5.0 result usually in failure.

An interesting point illustrated by the data in Table 1 is that 58 fields, or about 50 per cent of those examined, were very acid—too acid usually to produce a maximum crop. It is true that even on this very acid soil, below pH 5.1, 13 fields gave a yield of 250 bags per acre or more; but this small number compares unfavorably with the 45 fields having a similar degree of acidity where the yields were poor.

Table 1.—Influence of Soil Reaction on Yields of Onions.

pH range	Number of fields with yields in bags per acre of: 250 or more	200 to 250	150 to 200	Less than 150	Total
4.3 to 5.1	13	16	16	13	**58**
5.1 to 6.0	23	6	5	7	**41**
6.0 to 6.5	9	2	2	2	**15**

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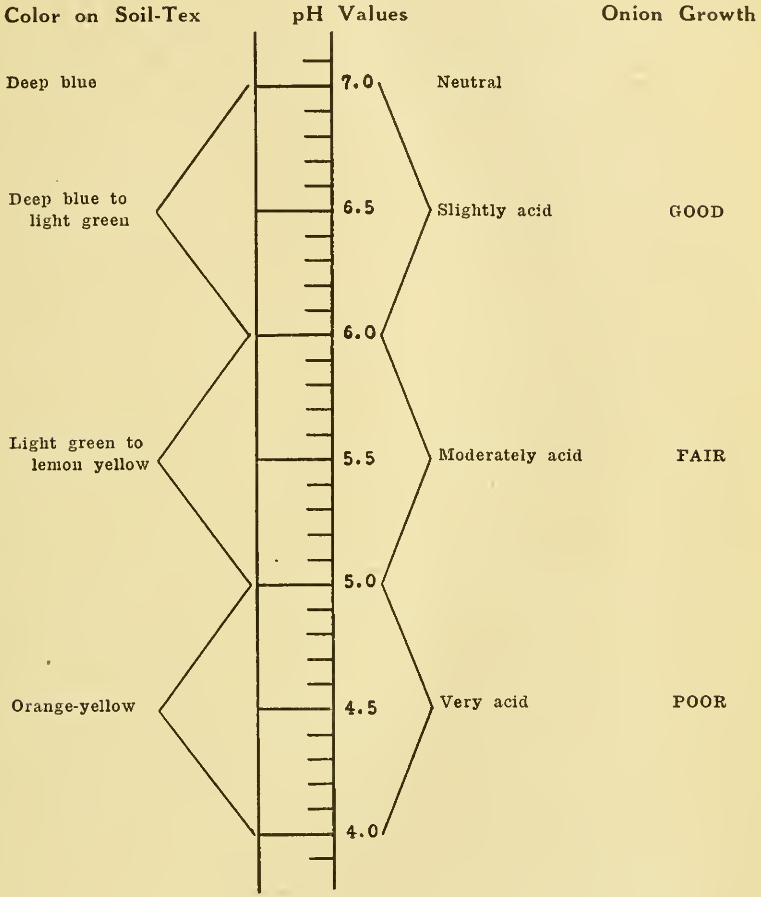
[1]. The writer wishes to thank Mr. Roland A. Payne, formerly County Agent of Hampshire County, for assistance in collecting soil samples and yield records; and also Mr. Orman E. Street, formerly of the Agronomy Department, for help in making pH determinations.

Figure 1. Graphical Representation of the Relation between Soil Acidity and Growth of Onions.


Color on Soil-Tex
pH Values
Onion Growth
Deep blue
Deep blue to light green
Light green to lemon yellow
Orange-yellow
7.0
6.5
6.0
5.5
5.0
4.5
4.0
Neutral
Slightly acid
Moderately acid
Very acid
GOOD
FAIR
POOR

Forty-one fields, or about 36 per cent, were found in the acid range of pH-5.1 to 6.0. In this group of less acid fields the yields were generally better, 54 per cent being 250 or more bags per acre. But even in this range of soil acidity there were far too many failures.

Few fields were found showing the more nearly neutral reaction. There were 15 fields with soils pH-6.0 or above in reaction. The yields from 9 of these exceeded 250 bags per acre.

It is apparent that most of the poor yields of set onions were from very acid soils, and most of the good yields from soils not so acid; and that lack of lime is responsible for many set onion failures. Other conditions, such as previous crop effects and poor sets, may be blamed in some cases.

Last Year's Crops Affect This Year's Onions.

To estimate better the value of lime for onions, attempt is made in Table 2 to eliminate as far as possible previous crop effects. Of the total fields of set onions in the survey, 88 were on land which would be called "old" onion land, whereas 21 followed tobacco grown the year previous.

Table 2.—Influence of Soil Reaction on Yield of Set Onions on Land with Different Crop Histories.

pH Range	Old Onion Land		Tobacco Land	
	No. of fields	Bags per acre	No. of fields	Bags per acre
4.3 to 5.1	45	208	12	145
5.1 to 6.1	37	250	7	148
6.1 to 6.5	6	291	2	193

Of the 88 fields of onions on the old onion land about half were very acid, and low yields of onions were obtained. On the less acid soils, pH-5.1 to 6.1, yields were increased by about 20 per cent; and on the still more neutral soils, pH-6.1 to 6.5, yields were about 40 per cent higher than those on the very acid soils with pH-4.3 to 5.1.

Onions following tobacco were in general very poor. Lime had been applied in a few cases, but this either had not been well worked into the soil, or had not been applied in amounts sufficient to neutralize the depressing effect of tobacco. The table shows by computation a difference of nearly 33 per cent between the yields on the most nearly neutral fields, pH-6.1 to 6.5, and those on very acid soils, pH-4.3 to 5.1. Even the highest yields secured, however, could not be considered to represent a profitable crop. There was a greater response to lime on the old onion land than on the tobacco land. The yields on the old onion land were very much better in each soil reaction range than on tobacco land cropped to onions in the year of the survey. These poorer yields may be ascribed either to the effect of the previous crop of tobacco, or to the fact that where lime was applied to tobacco after plowing, it remained chiefly on the surface, leaving the layer from three to six inches down very acid. It is also interesting to note that the chances of a good crop, even on very acid soil, are very much greater on old onion land than on land formerly in tobacco.

While it is occasionally necessary to shift from tobacco to other crops, or vice versa, yet the first crop following tobacco should not be onions. Unfortunately the state of our knowledge does not permit us to say what this crop should be. This problem is now under investigation in the newly instituted onion research work at the Experiment Station.

Lime Must Be Well Distributed.

Table 3 illustrates the fact that while the surface three inches of soil may be well limed, the three to six inch layer immediately underneath remains quite acid, at least for the first year following liming. This may mean that for many fields the lime must be applied to both sides of the furrow slice before maximum yields can be expected.

TABLE 3.—The Soil Reaction of Seven Different Fields as Affected by Method of Applying Lime.

Method of applying lime	Depth of soil sample	
	3 inches	6 inches
1. On surface	6.0 pH	5.8 pH
2. On surface	4.9	4.8
3. On surface	5.7	5.3
4. Both sides of furrow slice	6.3	6.3
5. Both sides of furrow slice	6.1	6.1
6. On surface	6.1	5.7
7. On surface	5.3	4.7

All the foregoing data refer to set onions. It was hoped that similar data might be taken for seed onions, but severe infection by onion mildew affected the crop to such an extent that it was impossible to determine anything very definite about the influence of soil reaction. At the Massachusetts Experiment Station, however, as shown in Table 4, increase in yield of seed onions was obtained with increase in lime up to two tons per acre. Beyond this amount no appreciable return was observed, although no detrimental effects were found from very large applications of lime. Onions that received lime showed darker green color, and more bushy tops, and seemed much more thrifty than the onions where no lime was applied. The relatively small yields were due in part at least to the mildew infection which occurred before the onions made very large bottoms.

Experiments were also conducted at Sunderland and North Hadley in the summer of 1926 in an effort to get further data on the value of lime for seed onions. Both of the fields selected for the experiment had grown onions for several years. Results in both of these places, respectively on the farm of Arthur Hubbard and W. F. Ryan, are included in Table 4.

TABLE 4.—Effect of Lime on Yield of Seed Onions. (Bags per Acre.)

Tons of lime per acre	Experiment Station fields	Field of Arthur Hubbard	Field of W. F. Ryan
0	85	275	191
½	—	—	239
1	122	293	215
2	159	329	244
3	171	—	—
4	158	—	—
5	167	—	—
6	179	—	—
7	178	—	—

The reaction of the onion soil on the Hubbard farm at Sunderland was medium acid, pH-5.5. A good crop of onions was secured. Hydrated lime had been applied in the spring. There was apparently response to its use, although not nearly as much as when it was applied to more acid soils. Similarly the experiment on the Ryan farm, North Hadley, indicated undoubted response to the use of lime, although a small quantity was apparently as effective as a large quantity in bringing about the desired improvement.

Yellow Tips May Indicate Acidity.

The best and most reliable guide to the degree of soil acidity is the soil test, but the plant growth on that soil is the most dependable criterion of the action of any particular degree of acidity. Set onions on very acid soil often start off well in the spring. Very shortly golden yellow tips appear—in some fields earlier than others. As the season progresses the yellow tips extend back on the leaves, with varying degrees of rapidity. In extreme cases older leaves soon become almost entirely yellow, lose their turgidity, and gradually curl downward and die; while the newer leaves, already yellow at the tips, gradually follow. In such a case very little growth is secured beyond that accounted for by the original set. There are found variations from this extreme to cases where only a few leaves are completely lost, to instances of slight yellowing of the tips, and to fields where none of this discoloration appears. With such variations, there are usually corresponding differences in yield. The yellow tips are always suggestive of an acid soil and the soil test usually confirms it.

In seed onions the symptoms are not exactly the same. In the early part of the season it is the stunting of growth, the absence of a bushy and thrifty appearance, the presence of slight yellowing of the tips that indicate a lime deficiency. Later in the season there is more yellowing and dying back of the tips and also a sluggishness in the formation of bottoms. These symptoms vary according to the degree and activity of the acidity.

When To Lime

Undoubtedly the best time to apply lime is in the autumn after the onions are harvested. It may be applied in the spring or even as a top-dressing after the onions are eight to twelve inches tall. Response to spring applications of lime is recorded above, but no data have been taken on the effectiveness of lime applied after the onions have begun to grow. All that can be said at this time is that a ton of limestone can be applied when the onions are eight to twelve inches high without injury.

Despite the fact that favorable results may be obtained from applications at other seasons, there are two chief reasons why lime should be applied in the autumn;—(1) there is a longer time for the lime to get thoroughly mixed with the soil, and the chances of altering the acidity before it injures another crop are much greater; and (2) it is usually more convenient to apply lime in the autumn and thus avoid the risk of not having time to do it in the spring. From both the soil fertility and farm management standpoints, therefore, it is good practice to apply lime in the autumn.

How Much Lime?

If the soil on test shows but moderate acidity—that is, if the color on the Soil-Tex scale shows yellow to slightly green—a ton of limestone per acre may be considered the minimum application; if it shows orange yellow at the bottom of the scale, then two tons is the minimum quantity to be considered. The growing crop should then be watched, and application in the following year based on its testimony. Consideration should always be given to the possibility of other crops being later grown on the onion land. If there is a likelihood of changing from onions to tobacco, caution must be exercised against applying too much lime. Tobacco does not do well on thoroughly limed fields, chiefly because of the black root-rot which thrives under this condition. Land that is limed sufficiently to grow good onions will seldom produce a full crop of tobacco until it has had time to become quite acid again.

Summary

1. Of the 114 set onion fields examined in the summer of 1926 a large proportion was found to be too acid to grow a miximum crop.

2. Crop measurements show better yields on the less acid soils. For any degree of acidity the yield following tobacco averaged poorer than following onions.

3. Both seed and set onions respond favorably to the use of lime.

4. Onions grow satisfactorily on a slightly acid soil. Sufficient lime to change the soil acidity to the point where it shows light green to bluish color with the Soil-Tex is all that is necessary.

5. Autumn is the best time to apply lime; but if the soil is very acid it is better to apply lime in the spring than not at all.

6. In using lime for onions, crops that are likely to follow must be given consideration.

7. On account of black root-rot, tobacco cannot be expected to produce a full crop on a well limed soil.

Publication of this Document approved by the Commission on
Administration and Finance

3 M. 10-'27. Order 321.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 238 OCTOBER, 1927

HEAD FORMATION IN APPLE TREES

By J. K. Shaw

In 1916 the Experiment Station laid out an apple orchard to be used for a comparison of six different types of pruning. The purpose of the experiment was to find how the trees reacted to certain definite treatments continued year after year. Results are reported in this bulletin in terms of growth and early production, with a series of tracings of photographs to show how individual trees developed under the various treatments. The ends to be gained by pruning are discussed, and directions given for pruning young trees at the time of setting and for several years thereafter, until the type of tree is established.

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AGRICULTURAL EXPERIMENT STATION
AMHERST, MASS.

HEAD FORMATION IN APPLE TREES

By J. K. Shaw

As a result of experiment and research during the past ten or fifteen years, our ideas of pruning young apple trees have undergone radical changes. These changes have been in the direction of less pruning, especially less severe cutting back of one-year wood. Since the literature reporting these investigations has been reviewed in many publications, no summary of previous work is attempted here.

Accordingly an orchard was laid out, devoted to a comparison of six different types of pruning, these being as well defined as the somewhat variable nature of the trees permitted. The project was planned in the expectation of finding how trees react to certain definite treatments continued year after year. It was hoped that the information thus acquired would replace opinion with fact in establishing a sound pruning practice.

Outline of the Experiment

The orchard of 600 trees was set May 10-15, 1916. The trees were all one-year whips about four feet high. The varieties chosen were Baldwin, Northern Spy, Rhode Island Greening, McIntosh and King. The basis of selection was partly commercial importance and partly varying habits of growth of the different varieties.

There were two rows of 60 trees each of each variety, planted 10 by 11 feet. Each experimental plot consisted of four trees, and each plot was five times repeated with each variety. Thus for each type of pruning there were 20 trees each of five varieties. In the spring of 1922, when the trees were six years old, one half of the trees were removed. The other half of the trees were continued to the close of the experiment in 1925.

The soil was a sandy loam classified by the Bureau of Soils as belonging to the Merrimac Series. It was of moderate fertility and had been more or less neglected for several years before the orchard was planted. One end of the area, comprising a little less than one-half the total, had been planted to nursery trees for three years. The growth of the orchard trees on this part was somewhat inferior the first season to that of the others planted on freshly plowed sod land. In an effort to remove this difference a moderately heavy application of manure was made to the poorer part in the spring of 1917. This resulted in some improvement, yet the trees on this part average slightly smaller than the others. This manure was the only fertilizer applied during the period of the experiment. The soil was kept cultivated and a non-leguminous cover crop sowed annually. The growth of the trees has been very good, as is indicated in the drawings reproduced herewith.

At the time this experiment was started there had begun to appear evidence that severe pruning was undesirable; hence the six types outlined below all contemplated rather moderate pruning.

1. *Globular tree, headed back.* The whips were cut back at planting at various heights depending on the variety. The Spy trees were cut at 24 inches, the Baldwin, King and McIntosh at 30 inches and the Rhode Island Greening at 48 inches. This last meant little shortening and with some trees none at all. In succeeding years these trees were thinned out each year and all one-year

shoots that had made over 6 inches growth were cut back from one-half to two-thirds, the pruning being less severe in later years.

2. *Globular tree, not headed back.* These were cut back at planting as in (1) and in succeeding years thinned to approximately the same degree, but no further cutting back was practiced.

3. *Unpruned.* These trees were not cut back at planting and were not pruned at all except to cut out suckers starting from the base and to keep the trunk clear of water sprouts.

4. *Modified leader.* Tree not headed back. These trees were not cut back at planting and in later years were thinned out as in (2). If a distinct leader persisted it was cut at a height of 8 to 10 feet, the cut being made at a side branch in two- or three-year-old wood.

5. *Leader tree headed back.* These trees were not cut back at planting, but in later years, while the leader was allowed to grow, all other shoots were cut back as in (1) though the cutting back was a little less severe; they were thinned out each year the same as the other pruned trees.

6. *Leader tree not headed back.* These were treated like (5) except that no heading back was practiced.

An effort was made to thin all the pruned trees of each variety to the same degree. This necessitated more cutting of the cut-back trees than of those not cut back. This program was carried out annually, except in 1920, from the start of the orchard until the spring of 1925 when the experiment was brought to a close. The pruning was always done by the writer, or under his immediate supervision. In the spring of 1920 no pruning was done owing to the absence of the writer, and the pruning in 1921 was somewhat more severe than in other years.

All prunings were weighed, the one-year wood and older wood being weighed separately except in the earlier years. The weight of the cut-back tips was also taken separately. Trunk diameters at a fixed point on the trunk were taken; the amount of bloom of each tree was estimated, and the fruit weighed each year. Other observations and measurements were taken from time to time as will be brought out later.

While the orchard has had a fair share of mishaps and it was necessary to replant a few trees, the stand of trees is as even as is often seen in commercial orchards. The most serious trouble met with was killing from the severe cold of the winter of 1917-18. The Spy and McIntosh did not suffer, but the Baldwin, Rhode Island Greening and King trees suffered rather severely. Some were killed back to the snow line; in others, while the bark and a thin outer layer of wood were uninjured, the rest of the wood was killed, resulting in a severe check in growth from which the tree recovered in a year or two. Further comment on the relation of this winter injury to the pruning experiments will be made.

Towards the end of this ten-year period the trees showed signs of nitrogen hunger and have since responded to nitrogen applications with better foliage color and increased growth.

Some of the trees proved untrue to name. The variety mixtures were as follows:

Baldwin, 10 trees, Stark and some unknown variety.
Northern Spy, 2 trees, Palmer Greening.
Rhode Island Greening, 30 Smokehouse and 1 Tolman Sweet
McIntosh, 1 Baldwin.
King, 2 trees an unknown variety.

As there were 120 trees of each variety, the proportion of misnamed trees was not large except in the case of Rhode Island Greening. Smokehouse is somewhat like Rhode Island Greening in its habit of growth though less vigorous. The misnamed trees are included in this report along with the others.

Results of the Experiment

Effect on Growth.

The wood removed in pruning each year has been weighed and the weights are given in Table 1. Considerably more wood was removed from the Baldwin, Northern Spy and McIntosh than from the Rhode Island Greening and King varieties. The reason for this is that the former varieties branch more freely and there are more shoots to cut. Moreover, King wood is more porous than the other varieties and therefore weighs less.

TABLE 1.—Weight of Prunings—average per tree

Variety and Type of Pruning	1917 *oz.*	1918 *oz.*	1919 *oz.*	1921 *oz.*	1922 *oz.*	1923 *oz.*	1924 *oz.*	**Total** *oz.*
		Baldwin						
Globular headed	1	11	24	89	84	63	77	340
Globular not headed	1	4	6	53	33	35	51	183
Modified leader	1	8	10	46	51	42	34	192
Central leader headed	2	12	14	106	76	53	63	326
Central leader not headed	2	10	10	60	49	35	32	199
		Northern Spy						
Globular headed	1	7	14	84	87	82	73	348
Globular not headed	1	3	8	50	40	51	36	189
Modified leader	1	5	11	48	43	48	38	194
Central leader headed	1	7	12	76	61	55	52	264
Central leader not headed	1	9	11	58	64	39	47	229
		Rhode Island Greening and Smokehouse						
Globular headed	1	5	9	52	18	36	61	171
Globular not headed	1	3	4	34	10	14	36	102
Modified leader	1	7	6	39	21	23	38	135
Central leader headed	2	8	9	46	32	39	63	199
Central leader not headed	1	7	5	30	16	23	45	127
		McIntosh						
Globular headed	1	6	12	75	55	74	173	406
Globular not headed	1	3	5	38	25	19	77	168
Modified leader	1	4	10	41	27	19	83	185
Central leader headed	1	7	11	60	48	53	122	302
Central leader not headed	1	5	5	34	24	16	57	142
		Tompkins King						
Globular headed	1	5	8	42	49	36	76	217
Globular not headed	1	2	3	26	10	9	29	80
Modified leader	1	2	5	18	9	11	35	81
Central leader headed	1	4	6	36	21	30	39	137
Central leader not headed	1	5	3	19	11	10	39	88

Much more wood was cut from the headed trees than from those not headed. Considering all varieties, the weight of wood cut from the globular headed trees was a little over twice the weight of that cut from the globular trees not headed.

In the spring of 1922 when the trees had made six seasons' growth, one-half of the trees were removed. They were dug by hand, the roots cut on a circle four feet in diameter, the soil was washed from the roots and the trees weighed. The results are given in Table 2, which summarizes the weight of about 300 trees. The unpruned trees weighed the most of all except in the cases of Spy and McIntosh, both free branching varieties. There are likewise two exceptions to the prevailing result that the cut back trees are lighter than those not cut back. The central leader trees not cut back were heavy trees, a result that appears in several other measures of growth. It should be noted that these trees had in general rather less wood pruned off.

Table 2.—Average Weight of Trees Removed, 1922

	Baldwin	Northern Spy	R. I. Greening & Smokehouse	McIntosh	Tompkins King	Average of all Varieties
	lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*
Globular headed	70	61	43	70	41	57
Globular not headed	76	58	54	79	53	64
Not pruned	93	62	63	93	62	75
Modified leader	77	64	55	87	43	65
Central leader headed	75	59	46	66	48	59
Central leader not headed	87	74	59	103	42	73
Average	80	63	53	83	48	

If to the weight of the trees at digging is added the weight of the wood pruned off before 1922, the figures shown in Table 3 result. This shows that the headed trees generally weigh less than those not headed, yet the difference is not great. The heaviest trees are the central leader not headed, which slightly exceed the unpruned trees.

Table 3.—Average Total Weight of Wood Produced

	Baldwin	Northern Spy	R. I. Greening & Smokehouse	McIntosh	Tompkins King	Average of all Varieties
	lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*
Globular headed	78	68	47	76	45	63
Globular not headed	80	62	57	82	55	67
Not pruned	93	62	63	93	62	75
Modified leader	81	68	58	91	45	69
Central leader headed	83	65	50	71	51	64
Central leader not headed	92	79	62	106	44	77
Average	85	67	56	90	50	

It has been shown[1] that there is no difference in height and spread of the trees except in the case of the headed trees, which are somewhat smaller than the others.

The average weights of the different varieties give an indication of the comparative vigor of these varieties. These differences are rather large. The McIntosh trees were heaviest, followed in order by Baldwin, Northern Spy, Rhode Island Greening and Smokehouse taken together, and King. The King trees were larger than their weight indicates, but owing to the porous nature of the wood the trees are light in weight.

The trunk diameters at a fixed point have been taken each year. Averages for all the trees in 1921 and for those remaining in 1924 are given in Table 4.

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[1] Mass. Agr. Expt. Sta. Bul. 226 p. 25, 1926.

It is doubtful if much significance can be attached to the differences appearing in this table. The central leader trees, not headed, again appear to be somewhat larger than any of the other groups. These trees are in each case at the south end of a series and as has been stated the soil is in general better towards the south end of the orchard. It is probably safe to conclude that the rather light pruning given these trees has not dwarfed them significantly except in the two groups where heading back has been practiced.

Table 4.—Average Trunk Diameters.

	Baldwin		Northern Spy		Rhode Island Greening and Smokehouse	
	1921	1924	1921	1924	1921	1924
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
Globular headed	81 ± 4	127 ± 9	76 ± 1	108 ± 2	63 ± 2	103 ± 2
Globular not headed	84 ± 3	135 ± 6	75 ± 2	103 ± 3	73 ± 3	116 ± 3
Not pruned	82 ± 4	122 ± 7	74 ± 1	109 ± 1	78 ± 2	117 ± 5
Modified leader	84 ± 3	129 ± 4	76 ± 1	112 ± 1	73 ± 3	115 ± 5
Central leader headed	88 ± 3	130 ± 4	74 ± 2	104 ± 3	72 ± 2	111 ± 5
Central leader not headed	90 ± 2	140 ± 4	81 ± 1	117 ± 3	78 ± 2	117 ± 6

	McIntosh		Tompkins King		**Average of all Varieties**	
	1921	1924	1921	1924	*1921*	*1924*
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
Globular headed	82 ± 2	129 ± 4	66 ± 3	113 ± 4	**74.2**	**116.0**
Globular not headed	82 ± 3	126 ± 5	70 ± 3	114 ± 6	**76.7**	**118.8**
Not pruned	82 ± 3	124 ± 5	78 ± 3	124 ± 4	**78.8**	**119.3**
Modified leader	88 ± 1	131 ± 4	65 ± 3	109 ± 5	**77.2**	**119.0**
Central leader headed	82 ± 2	127 ± 3	70 ± 4	111 ± 4	**77.5**	**116.6**
Central leader not headed	88 ± 1	130 ± 4	68 ± 3	111 ± 7	**80.1**	**123.0**

During the summer of 1922 the trunk diameter at a fixed point of the McIntosh and Northern Spy trees was taken at approximately two-week intervals from May 2 to August 16 and also September 14 and October 9. The results are shown in Figs. 1 and 2. These indicate that trunk growth continued at a fairly steady rate from May 15 to about September 1. Before and after these dates it was slower. The type of pruning seems to have had little effect, except that growth was a little slower in the case of the headed trees, especially late in the season.

The rainfall for June was excessive, while July and August had more sunshine than usual with a moderate rainfall. Possibly these conditions influenced the rather slow growth during the latter half of June and the increased growth during July and early August. McIntosh grew more rapidly than Spy during August which is in harmony with observations of the writer on nursery trees, where McIntosh grows more in late summer than most other varieties.

Measurements of shoot growth were made during 1922 on the Baldwin and McIntosh. Ten shoots on each tree were tagged and measured at weekly intervals from May 26 to July 14 with additional measurements on July 31, August 19 and October 12. The averages for the headed and not headed trees are shown in Fig. 3. This shows the later growth of the McIntosh. It also shows

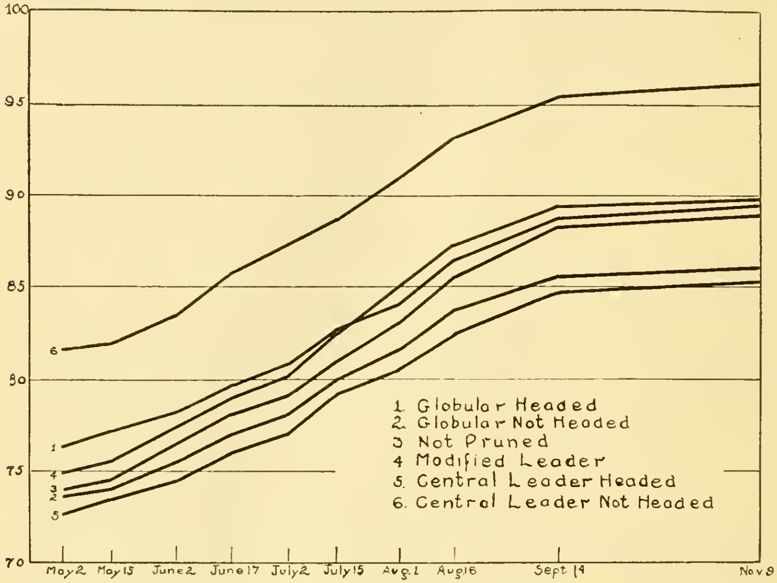

Figure 1. Trunk Growth of Northern Spy (in millimeters), 1922.

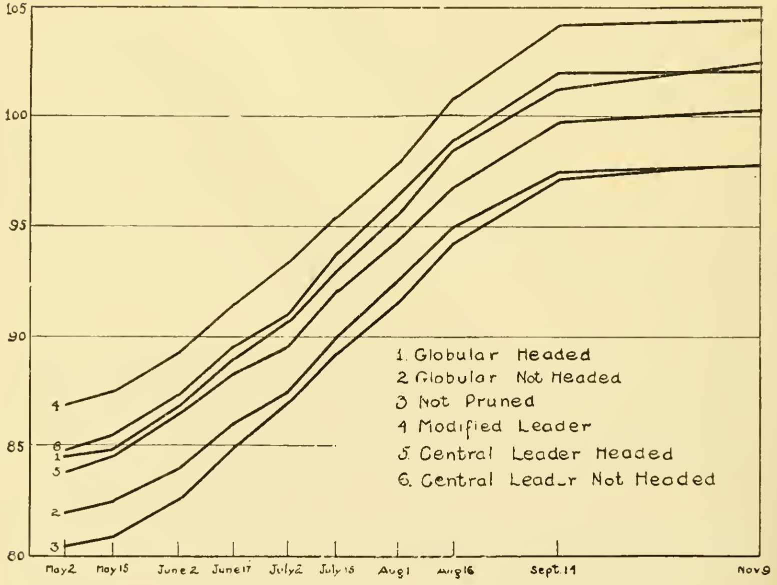

Figure 2. Trunk Growth of McIntosh (in millimeters), 1922.

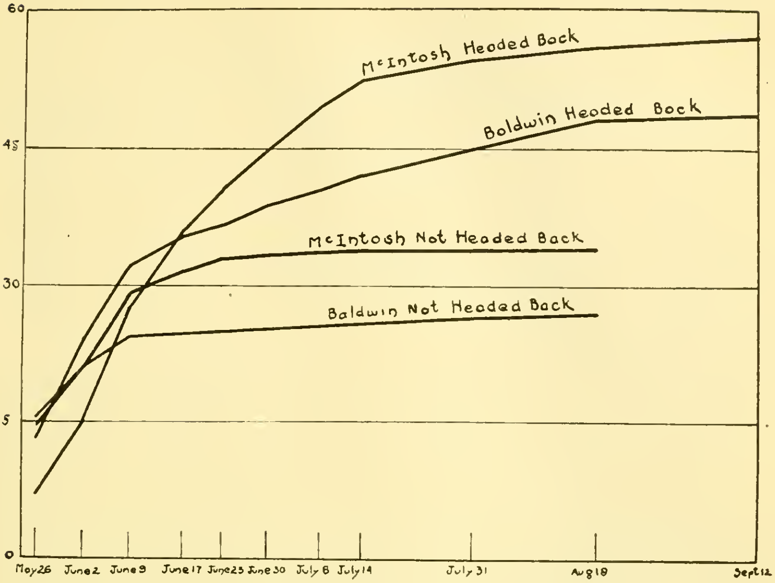

Figure 3. Average Shoot Growth (in centimeters), 1922.

that the headed trees started off somewhat slower than those not headed, but that they continued growing much later in the season. The shoots not headed had in most cases formed terminal buds by the middle of June, while the headed shoots continued growth for a month or more after that time. This is in harmony with common observations on this point.

Effect of Heading on Bud Development

In May, 1922, observations were made on the development of the lateral buds on the shoot growth of 1919 and 1920; that is, on the two- and three-year-old wood. A comparison of the performance of the buds on the headed and not headed trees is shown in Table 5. On the wood of 1919 the average total number of lateral buds was not materially reduced by heading, though they were reduced from 39.6 to 32.3 per cent on the wood of 1920.

The second column of Table 5 shows the percentage of buds remaining dormant at the time the count was made. On the 1919 wood the percentage of dormant buds was somewhat larger on the headed branches; but on the 1920 wood it was considerably less. This may have been due to seasonal differences, or to thinning out shoots in pruning. The differences in blossoming spurs are striking on the younger wood. Less than 1 per cent of the buds had developed into fruit buds on the headed branches, and on the older wood the percentage was much less than on the branches not headed. The number of non-blossoming spurs was larger on the headed branches of the older wood but somewhat less on the two-year-old wood. On the 1920 wood, nearly one-half of the buds on headed branches developed into leafy shoots; but on the older wood, only 12.9 per cent so developed. Probably many shoots had been pruned off in the process of thinning out the top. This table shows something of the manner in which heading reduced fruit bearing.

TABLE 5.—Development of Growth Points, May 1922

	Dormant buds	Fruit buds	Leaf spurs	Leaf shoots	**Total No. of growth points**
		Wood of 1919			
Headed	14.7	11.6	8.0	5.1	**39.4**
Not headed	13.6	18.0	4.6	4.3	**40.5**
		Wood of 1920			
Headed	6.3	0.3	11.9	13.8	**32.3**
Not headed	11.9	7.8	17.5	2.4	**39.6**

Effect on Bloom and Yield

This orchard has not produced much fruit. None has been borne by the Northern Spy trees, and the product of the Kings is negligible. The first crop of the other varieties was in 1922 and there has been a light to moderate crop each year since. The McIntosh trees have naturally borne the most, averaging over 4½ bushels per tree for the four years' total crop. The average percentage of bloom and the average yield per tree for the four years are shown in Table 6. The most significant fact brought out is the effect of annual cutting back. It has decreased bloom in every case, and decreased yield in all cases except the globular McIntosh. Probably the differences between the different types of pruning, not involving cutting back, and including the unpruned trees, are of no great significance. While the tops of the unpruned trees are pretty thick, no marked inferiority of the fruit in either size, color or quality has yet appeared.

TABLE 6.—Bloom and Yield, 1922-1925, inclusive.

	AVERAGE PERCENTAGE OF BLOOM			TOTAL YIELD PER TREE—FIRST FOUR YEARS OF BEARING			
	Baldwin	Rhode Island Greening	McIntosh	Baldwin	Rhode Island Greening	McIntosh	**Total, three Varieties**
				lbs.	*lbs.*	*lbs.*	*lbs.*
Not pruned	4	13	29	48	55	197	**300**
Globular headed	1	10	13	17	34	160	**211**
Globular not headed	2	17	21	42	51	141	**234**
Modified leader	4	18	31	41	52	256	**349**
Central leader headed	1	16	18	9	32	140	**181**
Central leader not headed	2	24	28	32	34	223	**289**

Summary of Experimental Studies

This section is based in part on the data and observations presented in this bulletin and in part on a previous publication.[1]

All things considered, probably a system of pruning similar to the modified leader type is most desirable.

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[1] Mass. Agr. Expt. Sta. Bul. 226, 1926.

The rather light pruning followed in this experiment has not dwarfed the trees nor decreased yields appreciably, except where heading back the new growth has been practiced.

Heading back the new growth has removed more wood, made a denser top, favored a more upright growth, and dwarfed the trees somewhat. It has also delayed the start of shoot growth slightly and distinctly prolonged the growing season of the shoots. It slightly increased the rate of shoot growth and checked cambial growth. It decreased bloom and yield as long as it was practiced. It caused the growth of a greater number of shoots the year following pruning.

The globular headed tree was most successfully produced, but this type is not desirable. The central leader tree failed in many cases, especially where the side branches were not headed back, most of these becoming modified leader trees. Most of the unpruned trees could be classified as modified leader trees. This may, perhaps, indicate that the modified leader type is the natural form for most varieties of apples. If one desires to produce a central leader tree, vigorous vegetative growth and pruning the scaffold branches are necessary.

Interpretation of Experimental Evidence

It is perhaps true that much of the pruning in the past was worse than no pruning. It would be better to leave the young tree unpruned than to cut it back severely and without discrimination. If, however, the tree is pruned lightly and with understanding, growth may be controlled and directed toward the production of more satisfactory and uniform trees than would result if they were left to themselves.

The Purpose of Pruning

In order to prune intelligently, a clear understanding of the purpose of pruning is necessary. This may be outlined under the following heads:

1. To produce a well balanced, mechanically strong tree.

This means that the permanent scaffold branches will be of about equal size, well separated up and down, and evenly distributed around the leader or trunk. One branch should not be directly above another even if they are separated by a considerable distance. It is probably not desirable to have even two branches at the same height. Certainly three branches at the same height will seriously dwarf the leader above and any scaffold branches arising from it, resulting in a weak tree.

Mechanical strength is secured by having the scaffold branches originate through a strong shoulder at the place of origin. To get this the branch angles should be wide and the branch smaller at the point of origin than the leader. The initial growth of the branch should not be too strong. Branches coming out at a narrow or very acute angle are likely to develop layers of bark between the branch and leader instead of a bridge of wood. The former means a weak crotch that is almost sure to split with the first heavy crop of fruit, while the latter gives a strong crotch that will not split. The Baldwin tends to form narrow angles while Rhode Island Greening and McIntosh tend to form wider branch angles with bridges of wood across which give strength, enabling the trees to carry heavy loads of fruit without splitting.

2. To direct growth toward the production of the maximum quantity and quality of fruit throughout the life of the tree.

This statement attempts to summarize the chief economic purpose of growing fruit trees. What sort of a tree will accomplish this purpose? The first step in fruit production is the formation of fruit buds. It seems to be true that fruit bud formation accompanies the accumulation of starch in the tissues. Ample leaf area and good exposure to sunlight are essential to starch formation. If spur leaves are shaded, or if some or all of them are removed, the chances of fruit bud formation are reduced. But if active growth is going on in the vicinity of potential fruit buds, the accumulation of starch is lessened, even though it is being formed in liberal amounts; it is used up in new growth. Hence, to secure fruit buds we must have a large spur leaf area well exposed to sunlight and a relatively early cessation of shoot growth. These conditions are found in trees producing a heavy bloom.

Not only must there be an accumulation of starch but also an adequate supply of water and mineral matter, especially nitrogen, coming up from the soil. This must be abundant enough early in the season to insure leaf growth, but it should be restricted soon or it will favor too long continued growth with heavy consumption and lessened accumulation of starch.

In pruning young trees so as to prepare the way for future fruitfulness the development of many spurs should be the first objective. It has been shown that heading back one-year wood and shading decrease the number of spurs. The converse of this avoiding heading back and securing good exposure to light, should increase the number of spurs. In order to get good light exposure the branches should come out at a fairly wide angle, perhaps from 45° to 90°. The leaves on an upright branch are shaded by the leaves above, and if there are several upright branches they shade each other. It is often claimed that a dense head will so decrease the light exposure as to interfere with fruit bud formation. This may be true, but there is no indication that the rather dense heads of the unpruned trees in this experiment have bloomed less freely than the more open pruned trees. Perhaps the real trouble with dense trees that fail to bloom well is often a too prolonged period of growth. This results in a heavy blanket of foliage which shades the spur leaves more than would a greater number of shoots making a short annual growth.

3. To secure the maximum growth commensurate with strength and future fruitfulness.

The more rapidly young trees grow, the sooner they will be of a size to produce profitable crops. Early bearing may or may not be profitable when it is secured at the expense of growth. It has been shown that a large shoot growth comes through length of growing season rather than through rapid growth. It may be that very late shoot growth is more liable to winter kill, yet we have seen soft tips come through rather severe winter weather without injury. Late cambial activity is more dangerous than late shoot growth. Probably it is not dangerous if terminal bud formation is delayed until late September or early October, though as has been shown fruit bud formation is likely to be less in such trees. Late growth is sought after in nursery trees, and winter injury to the tips rarely follows though bark splitting at the base of the trunk of late growing trees is often seen when rather severe cold occurs in November. This frequently occurs in McIntosh, which is one of our hardiest varieties. It seems, then, that a long season of shoot growth in young trees is desirable, but cambial activity should cease in late September. Such conditions are brought about by soil management rather than by ordinary pruning.

There are objections to too rapid growth. It favors upright growth and narrow branch angles. Probably very rapid growth is not desirable the first two or three years when scaffold branches are being established, especially in upright growing varieties. Then vigorous growth may be encouraged until the trees are large enough to bear profitable crops.

How to Prune

The purpose of the experiment was to find how the trees reacted to certain definite treatments continued year after year. Some of the trees are now well formed and seem of the type that should produce satisfactorily. Most such trees are among the modified leader, central leader, and unpruned types. In fact, with a little thinning out of branches, many of the unpruned trees would be as satisfactory as those of any other class. Yet some of these would be stronger and more satisfactory had some of their main branches been pruned when small so as to prevent their outgrowing other branches.

Both types of headed trees are unsatisfactory. They tend to be upright and have too much bare space along the branches and too few laterals and spurs. The globular trees not headed are intermediate. Some are strong, well-formed trees; others have some of the faults of the headed trees.

Pruning at Setting

One-year whips may be set without pruning if not too tall. Trees over four feet tall may be cut back, especially if of upright growing varieties. Leave two to four feet according to the variety, taking care to have plenty of strong buds on the part left.

In pruning two-year trees, leave the strongest and most upright branch for a leader, cutting it little or not at all. Remove or cut back severely any branches competing strongly with this leader, as well as all strong branches having narrow, weak crotches. Leave well-located, fairly vigorous branches having strong crotches, as temporary or permanent scaffold branches. Cut them back only for the purpose of holding back those that are outgrowing the rest of the tree. This treatment will usually remove enough top to restore the balance between top and root that has been upset by transplanting the tree.

Pruning the Second Year

Do not cut back the leader unless it is far in advance of the side branches. Remove or cut back severely any branches developing narrow, weak crotches. Continue the selection of strong, well separated and well distributed branches as temporary or permanent scaffold branches. Cut back any that are outgrowing the rest of the tree. Remove or cut back any that are nearer than about six inches, and any coming out directly above another even if separated by a considerable distance.

The Third and Succeeding Years

It is during the second and third growing seasons that the future shape of the tree is largely determined. If growth has been wisely directed during these two seasons, pruning in later years consists in carrying on the development already started. Remove or cut back severely branches with narrow angled crotches and lacking a bridge of wood across the angle. Prune with appropriate severity any scaffold branch that outgrows its fellows. Avoid the development of one scaffold branch directly above another, even if separated by some distance.

Do not allow a scaffold branch to compete with the leader, but keep the leader ahead by pruning its competitors.

Give the same treatment to any lateral growing out of a scaffold branch; if it competes with the leading shoot of the scaffold branch, cut it off. Stating this a little differently, whenever a branch divides into two shoots of about equal strength, remove one at the first opportunity.

Pruning a scaffold branch or lateral to prevent it from outgrowing its fellows should be done early in the life of the tree. The sooner the necessity for cutting is seen the less will be needed and the less the leaf surface will be reduced. Young trees should be pruned as little as possible and no branch cut back or removed without good reason. Corrective pruning is, however, highly important and often absolutely necessary in order to grow a strong, well-formed tree that will produce a maximum of high grade apples.

The drawings in Plates I-XVI are made from photographs. The figures indicate the age of the tree at the time the photograph was made, and the letters *b* and *a* indicate before and after pruning, in each case where they are used. No photographs were taken at four years because of the absence of the writer, and at five years the trees were too close together to permit setting up a camera. After one-half of the trees were cut out at six years of age photographs were again made each year. There is little difference between the photographs at six and seven years, and generally only the latter are shown. The camera was set at nearly the same position relative to the tree each year, though with increased size of tree it was necessary in later years to set farther away.

In these drawings the development of the different branches may be followed from year to year, showing how they responded to the treatments given.

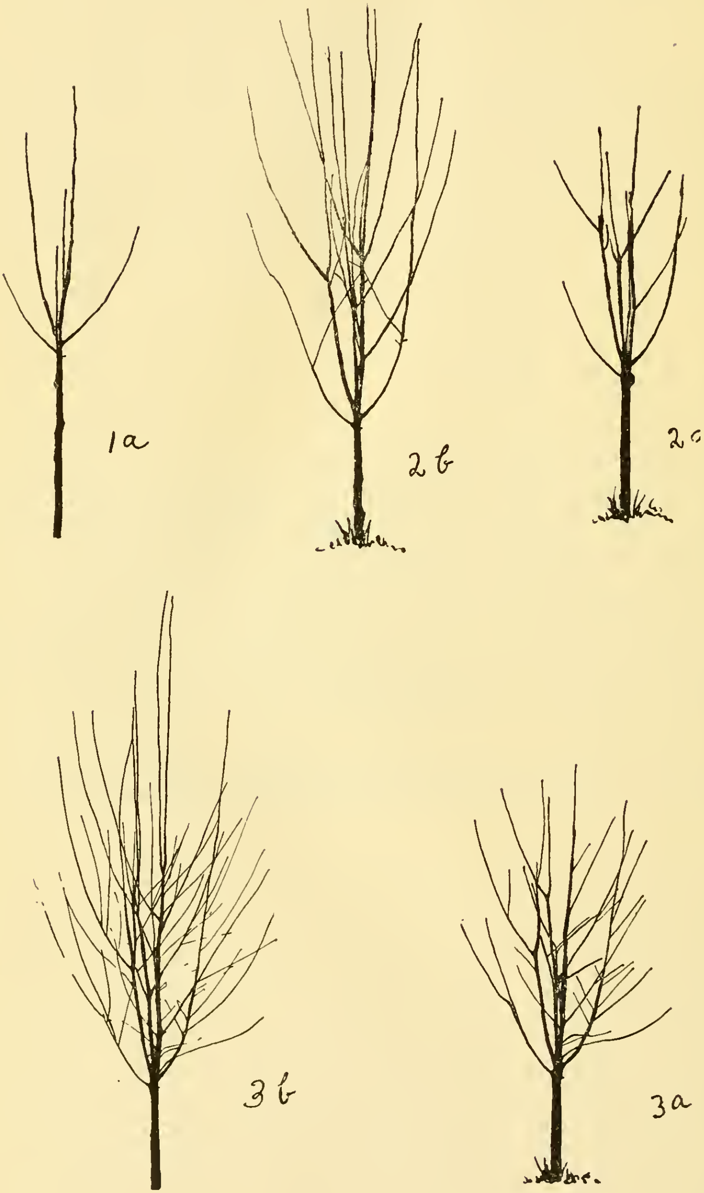

1a
2b
2c
3b
3a

Plate I. Northern Spy Tree D44. Globular headed.

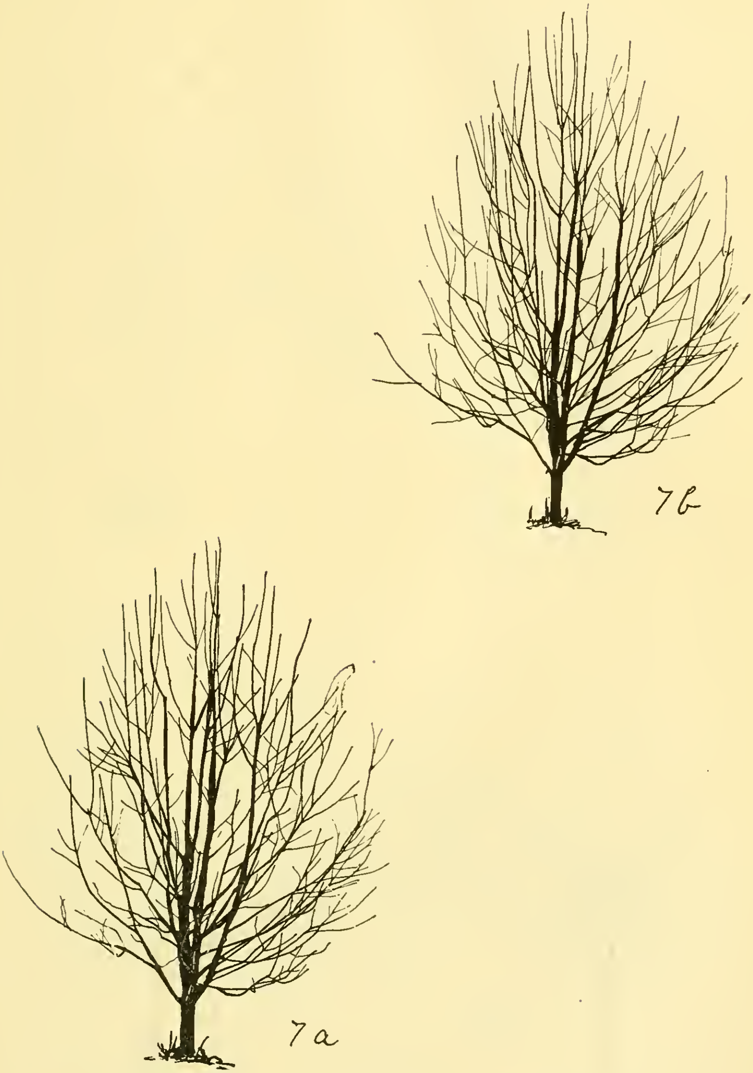


Plate II. Northern Spy Tree D44, at seven years.

Note the upright growth induced by severe cutting back. The strong upright scaffold branches shade each other and, even though the tree was cut back to two feet at setting, the tree is fully as high-headed as the trees which were not cut back at setting. The severe heading back results in a dense top that must be thinned severely the next year. This type of pruning is not desirable.

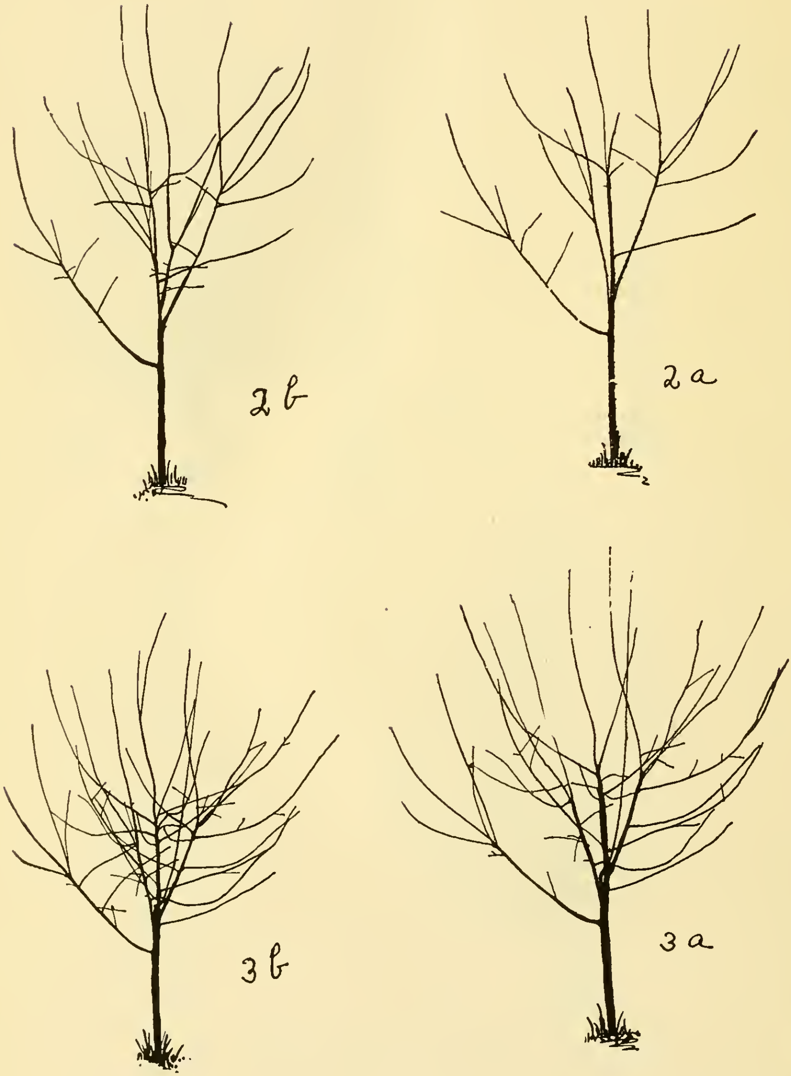


Plate III. McIntosh Tree H38. Globular not headed.

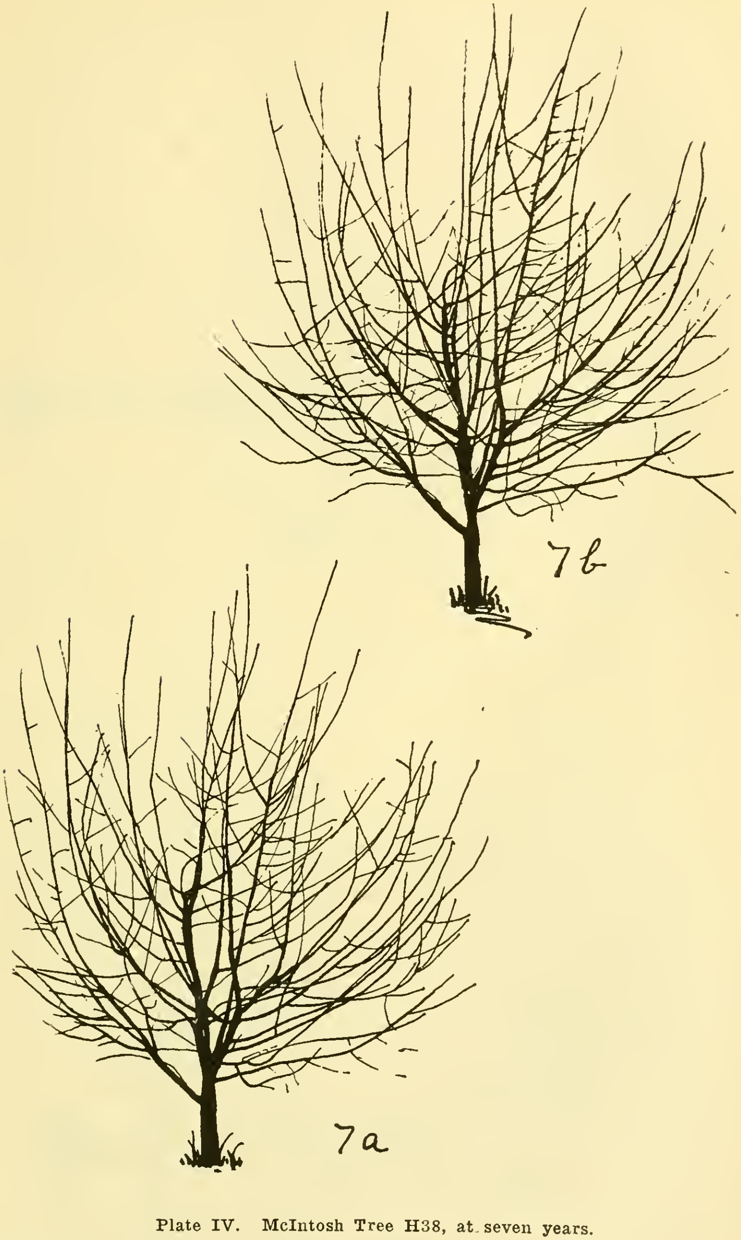


Plate IV. McIntosh Tree H38, at seven years.

The one-year whip was cut back at planting with the result that three or four branches came out at about the same point. Follow the development of the lowest branch at the left. It would perhaps have been better to cut this back at first, yet the tree has gained symmetry with age. The main branches shade each other which has probably lowered production. Total yield 222 pounds. Compare with Plate XIV.

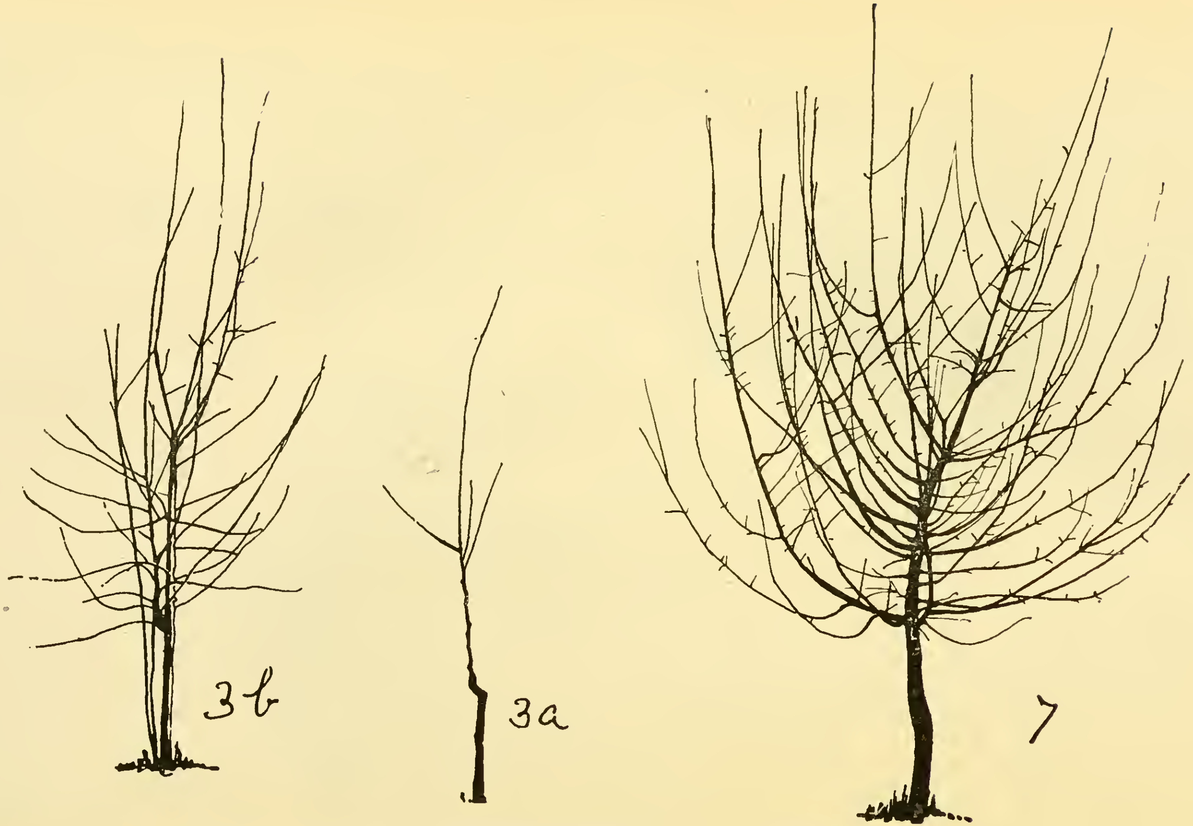


Plate V. Rhode Island Greening Tree L46. Unpruned.

Killed back to snow line in winter of 1917-18. 3a shows the tree after the dead part was cut away leaving a strong upright shoot that developed into a good tree, shown in 7. Some of the scaffold branches should be removed.

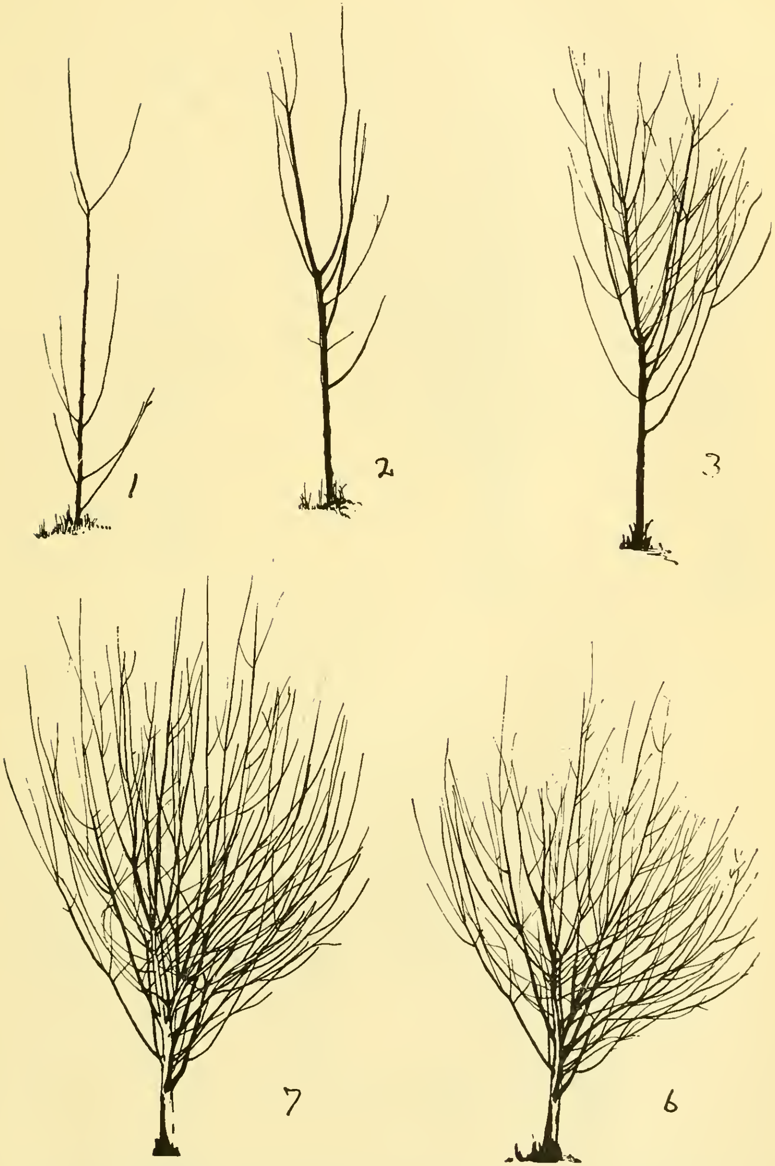


Plate VI. Northern Spy Tree D48. Uupruned.

The lower branches in 1 were cut off. A better tree would have resulted if the leader in 1 had been cut back. Probably thinning out the top and spreading the top by cutting to outside branches would have improved the tree.

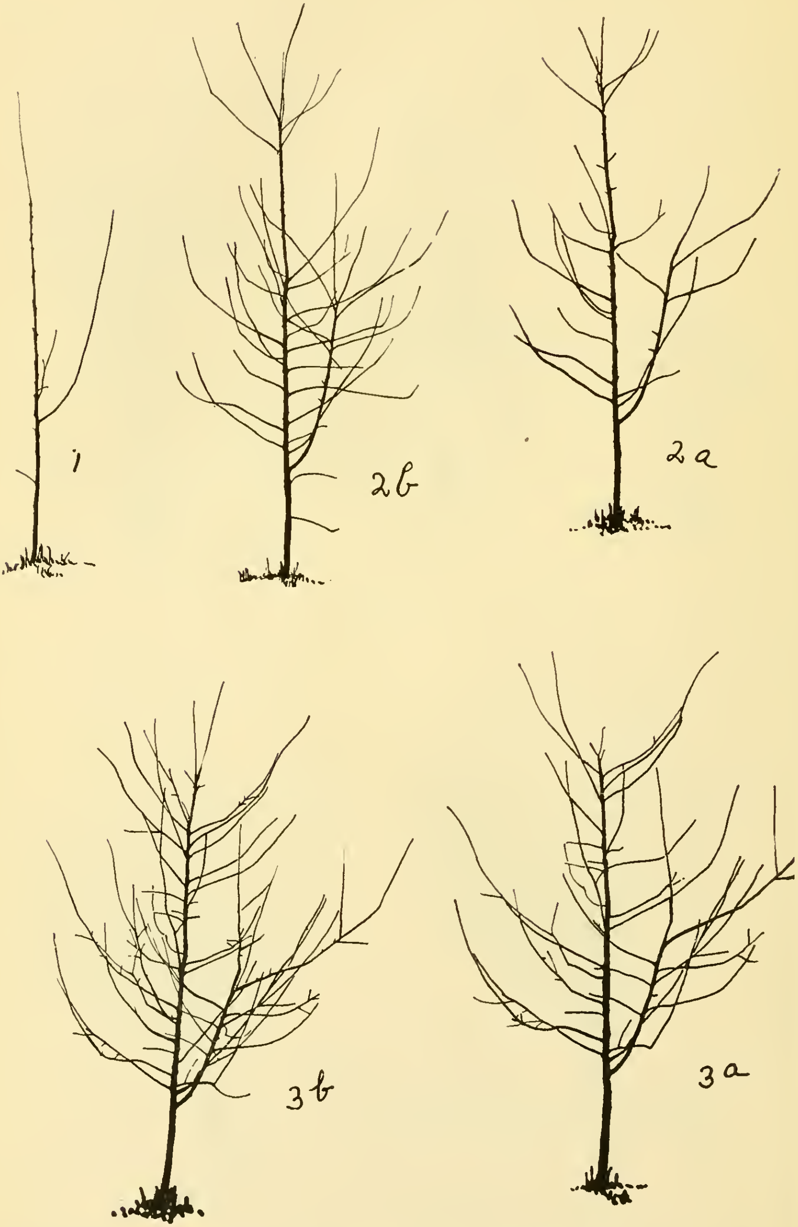


Plate VII. McIntosh Tree H46. Modified leader.

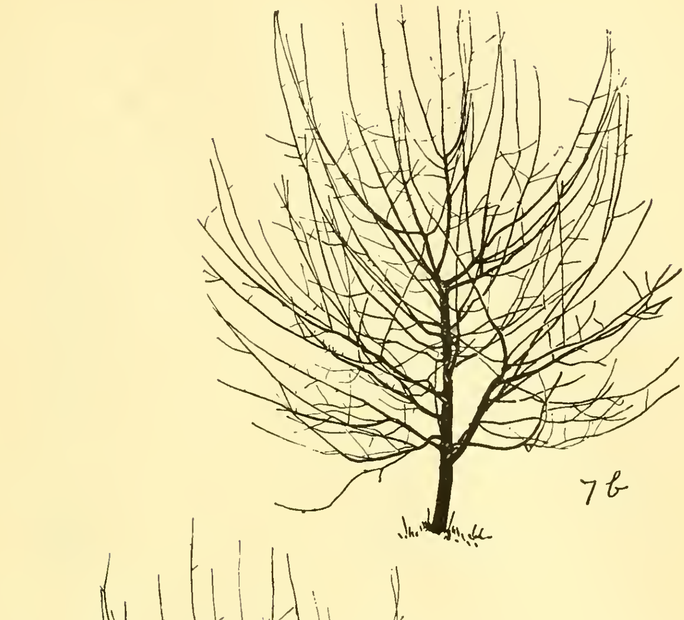


Plate VIII. McIntosh Tree H46, at seven years.

Follow the development of the branch shown on the right in 1. In Plate VII this has developed strongly and suppressed branches above. It should have been cut back severely or removed the first year. Note the suppression of the leader in 3a. Probably it should have been checked sooner, as that would have prevented the heavy growth of the upper branches shown in Plate VIII. These strong branches shade and thus check the lower branches. Total yield 473 pounds.

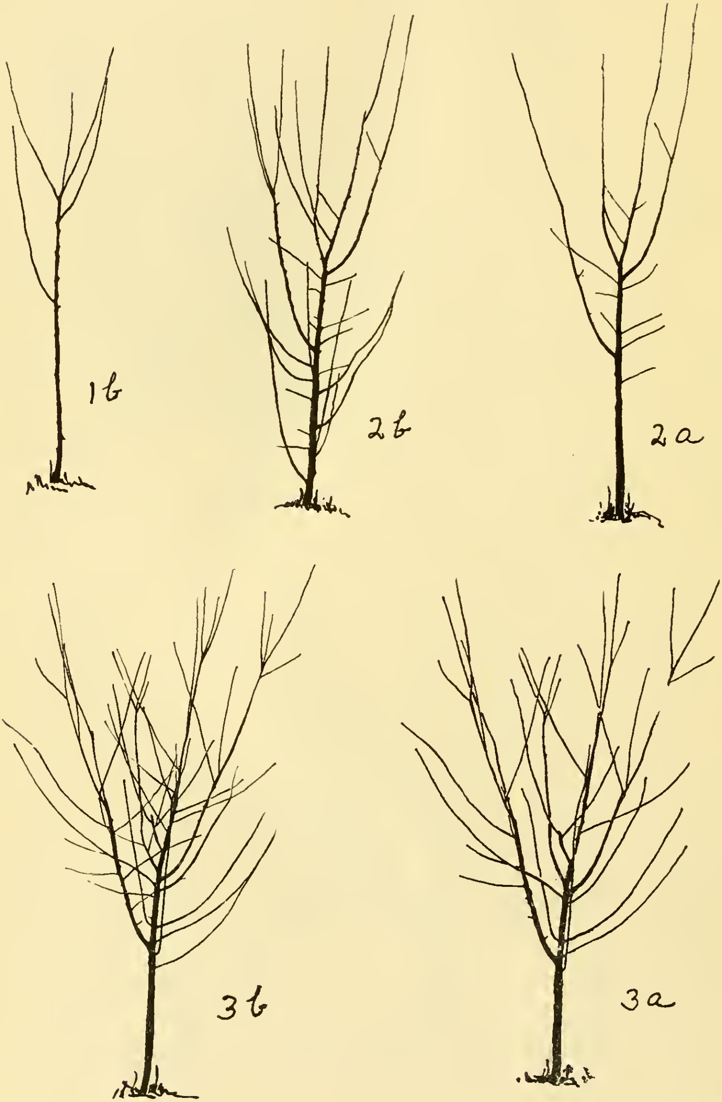

1b
2b
2a
3b
3a

Plate IX. Baldwin Tree B48. Modified leader.

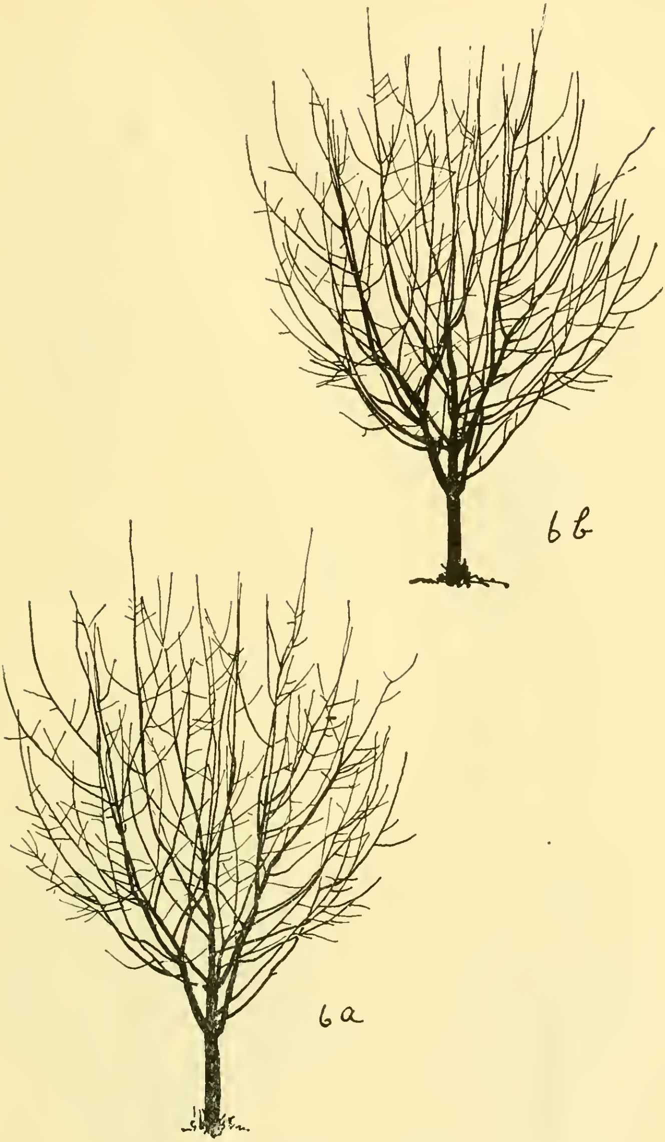


Plate X. Baldwin Tree B48, at six years.

The four branches of the first season's growth, shown in 1b, continue to dominate in later years, and a strong well-formed tree resulted. No suppression of the leader was necessary for, as the figures show, it never dominated very strongly. Possibly an effort to spread the tree by cutting to outside branches would have made a better tree, but it is a good one as it is. It will spread without breaking when it comes in bearing. A careful study of these figures will give valuable hints as to the way to prune young trees.

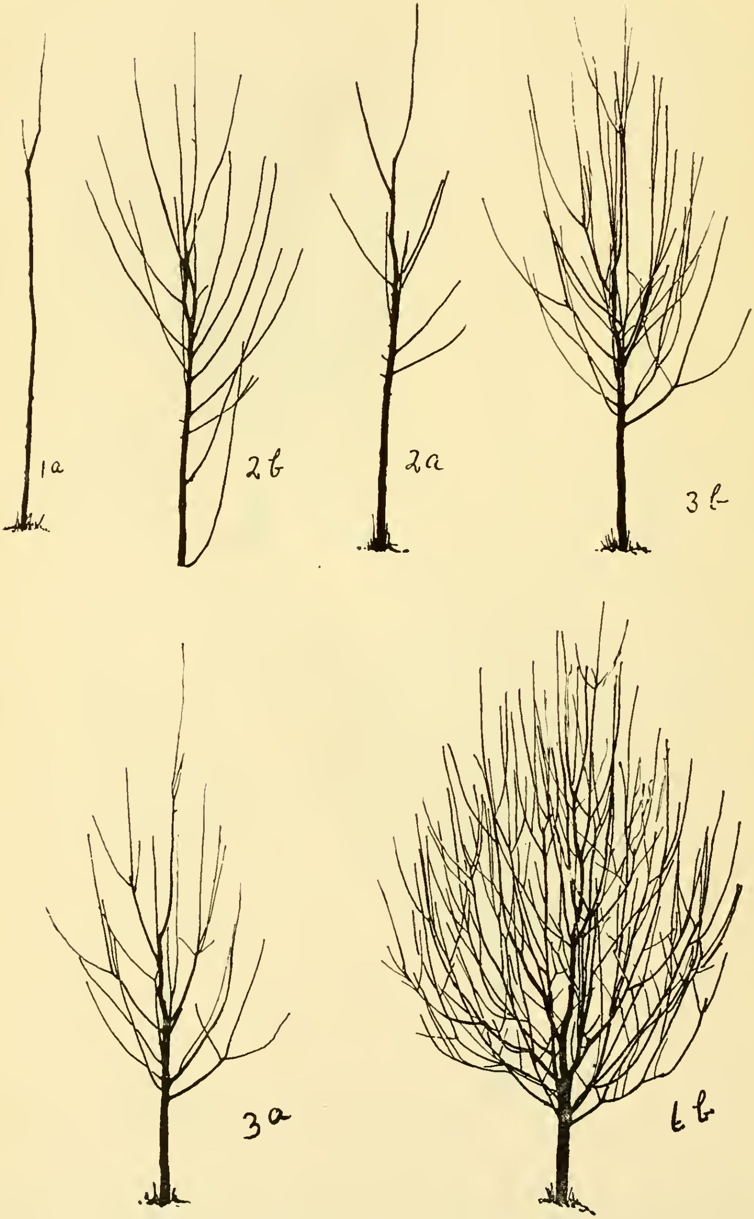
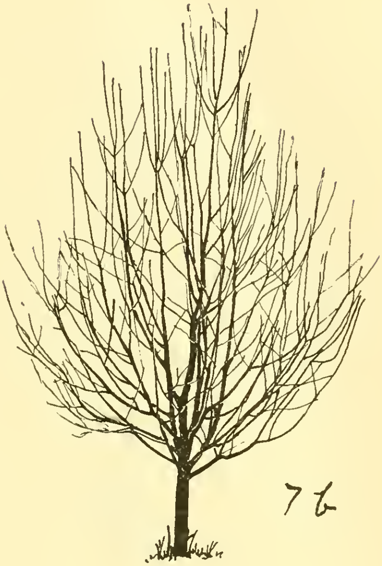
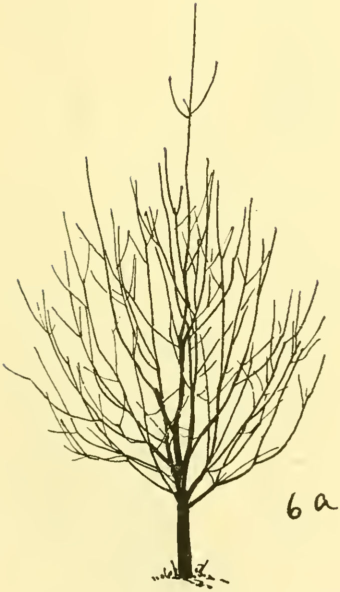

1a
2b
2a
3 b
3a
4 b

Plate XI. Northern Spy Tree D56. Central leader, headed.



7b



6a

Plate XII. Northern Spy Tree D56, at six and seven years.

These figures show how heading back the branches while allowing the unhindered development of the leader has favored the development of a leader tree. This heading back has necessitated much thinning out of one-year twigs the next year. The tree is not as large as it would have been if it had not been headed back. This type of pruning is worse than none at all.

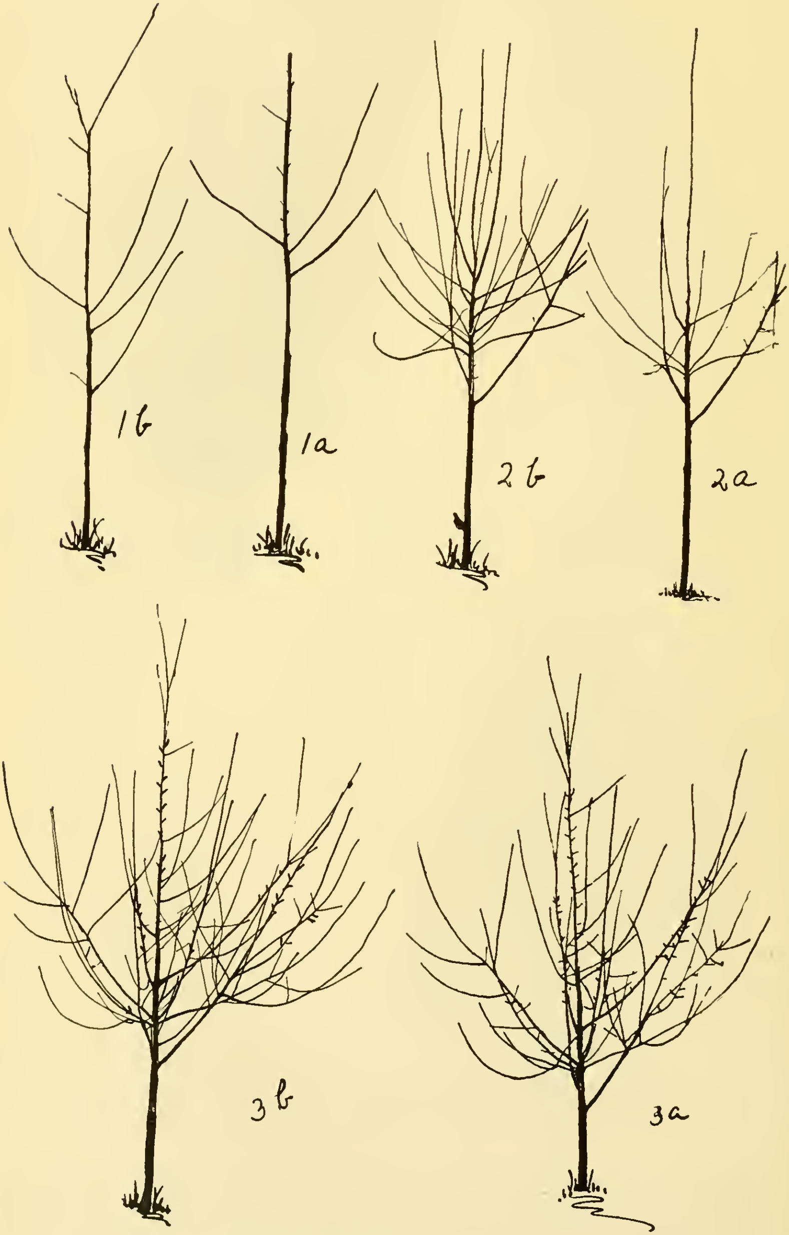

1b
1a
2b
2a
3b
3a

Plate XIII. McIntosh Tree H34. Central leader, not headed.

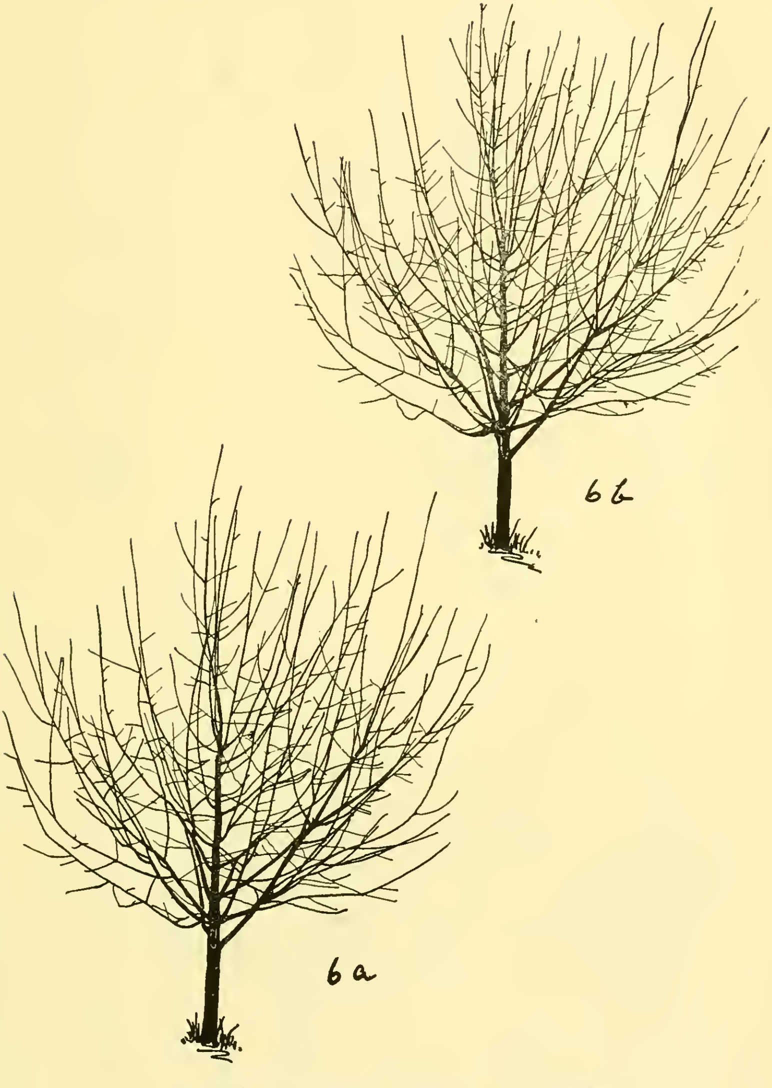


Plate XIV. McIntosh Tree H34, at six years.

Cutting back of the top shown in 1b, as shown in 1a, resulted in three strong shoots as shown in 2b. Two of these were removed as shown in 2a, leaving a long leader which perhaps should have been shortened. Still, a well-formed tree resulted which has borne 773 pounds of fruit, the most of any tree in this orchard.

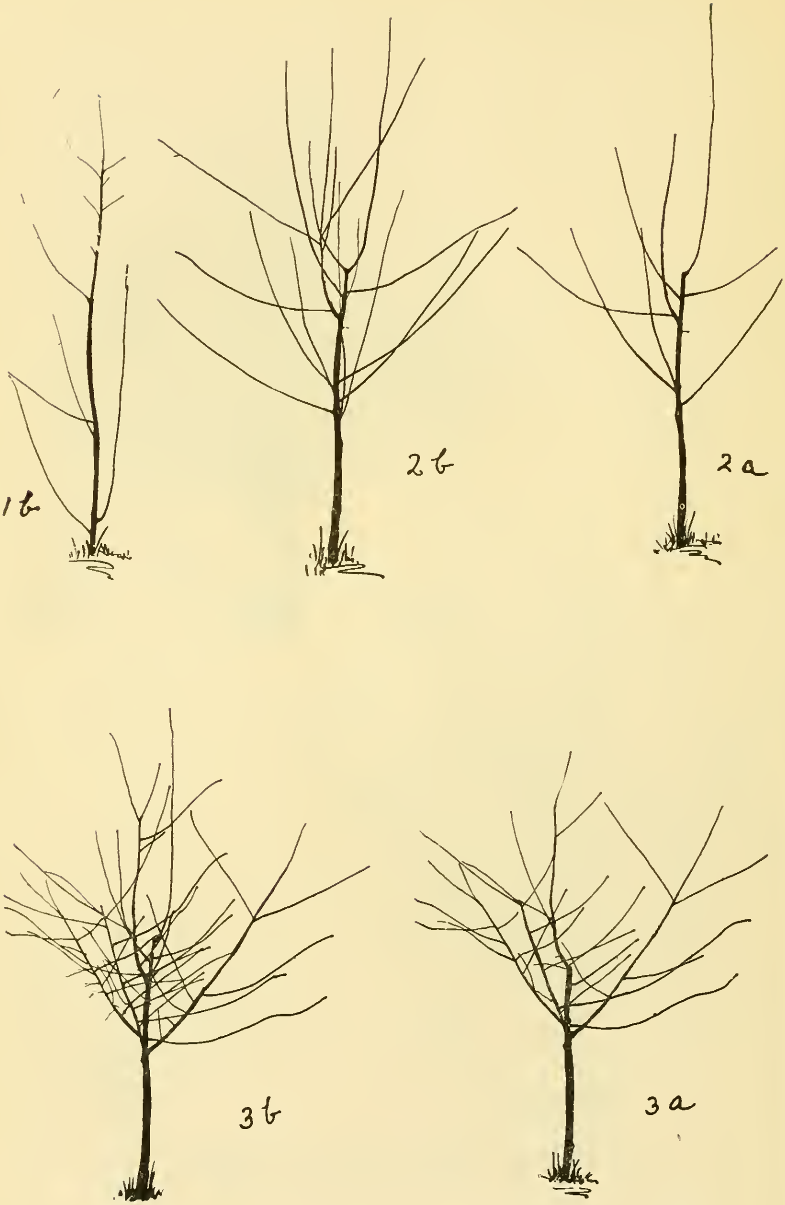
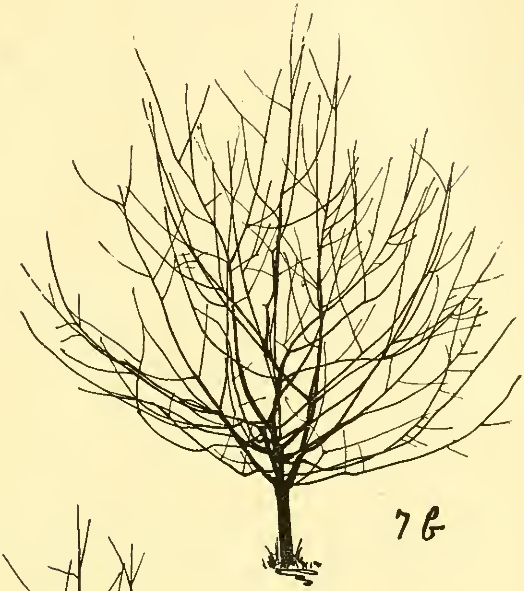

1 b
2 b
2 a
3 b
3 a

Plate XV. Tompkins King Tree J32. Central leader, not headed.



7b

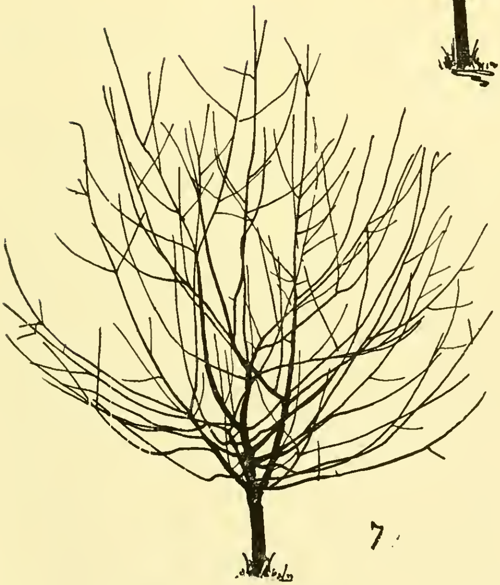


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Plate XVI. Tompkins King Tree J32, at seven years.

The leader shown in 2 and 3b is dead from the severe cold of the winter of 1917-18. 3a shows the tree after the removal of the dead leader, and 7 shows a well-formed tree resulting. The growth of the leader in the young tree need be only moderately stronger than the scaffold branches in order to secure a strong, well-balanced tree.

Publication of this Document approved by the Commission on Administration and Finance

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 239 FEBRUARY, 1928

Cape Cod Cranberry Insects

By HENRY J. FRANKLIN

The cranberry is the most important export crop of Massachusetts, with a value of two and one-half to five millions dollars annually. Some 14,000 acres are devoted to its culture, most of which would otherwise be waste land. Insects take an annual toll of about one-fifth of the crop. Since the establishment of the Cranberry Station, therefore, a great deal of study has been given to these pests and methods for their control. This bulletin brings together the knowledge and experience gained through many years, and presents it in a form readily accessible to cranberry growers. Important features of the bulletin are the colored plates and other illustrations showing cranberry insects in their different stages as well as the various ways in which they injure the plant.

Requests for bulletins should be addressed to the
AGRICULTURAL EXPERIMENT STATION
AMHERST, MASS.

ACKNOWLEDGEMENTS.

The writer acknowledges his many obligations to all who have helped him in the studies, the results of which are assembled here: especially to the cranberry growers who everywhere for many years have given him the freedom of their bog properties and every encouragement; to his coworkers of the Massachusetts Agricultural Experiment Station and the United States Department of Agriculture for naming specimens and for cooperation in the study of special problems; to H. B. Scammell for valuable information about the habits and life histories of some of the pests; and to his assistant, J. L. Kelley for his constant faithfulness and efficiency.

Thanks are due the Cape Cod Cranberry Growers' Association for the colored plates donated for this bulletin and for other services rendered.

MATTERS OF GENERAL IMPORTANCE IN BOG MANAGEMENT

A plentiful water supply for flooding whenever necessary is the best and cheapest insurance against insect injury on cranberry bogs, and it should be provided if the cost is not prohibitive. Where a water supply is lacking or inadequate, spraying, sanding or other measures must be adopted.

Special attention should be given the various pests in those years when the crop prospect is poor. If they are properly reduced then, they often may be neglected safely when the crop promises to be heavy. Any known treatment, be it flooding, sanding, or spraying, is likely to injure the vines more or less and so reduce the crop. The amount of this reduction usually is directly proportional to the crop promise. Unfortunately, most growers fit their bog management to the condition of their finances, present or prospective, rather than to that of their bogs. Limited water supplies for reflooding should be used mainly to control pests, and long chances may be taken with frosts in the years in which the bogs concerned promise a short crop so that when the crop promise is good, chances may be taken with the insects and the water may be used for frost protection.

Bog managers should learn to gauge insect infestations in their early stages so as to know when attacks may be neglected. The insect net is as important as any other bog equipment. The bogs should be examined with it every four days from May 10 till mid-July. For practical purposes the sweeping with the net may be done at any time of day, though it usually collects rather more cutworms and gypsy moth larvae as soon as the dew is off in the morning and just as it begins to form in the evening. If 50 sweeps of a net 11 inches in diameter gather from the vines over 12 gypsy moth caterpillars or cutworms of any kind, or more than 48 spanworms, the infestation should be treated anyhow. Six cutworms or gypsy moth caterpillars and 24 spanworms are equivalent to 12 cutworms or 48 spanworms, four spanworms equalling one cutworm in their capacity to do harm. As the worms of most of the species grow larger they cling more and more to the vines or hide under them and so are gathered by the net in smaller and smaller numbers.

The worms that float ashore during flooding treatments seldom give any trouble. Usually most of them thrash themselves to death in the water and few have life enough left to eat afterward.

Bogs never should be burned off to control insects unless the vines are so deep and snarled that their renewal is desired. Even then it is often better to mow them.

It is necessary to *success* in cranberry culture to control all the pests recognized generally by the growers as harmful, but it is essential to *real efficiency* to check also the horde of minor forms that usually escape notice, such as leafhoppers, black bugs, springtails, spittle insects, mites, aphids, etc., which in the aggregate greatly drain the vitality of the vines on many bogs and so reduce the quantity and quality of the fruit produced.

Cranberry insect problems present so many conditions that it is hard to cover them all fully in bulletins. Chances to check two or more pests with one treatment always should be looked for. Those that occur commonly are indicated in the discussion of the various insects.

CAPE COD CRANBERRY INSECTS

By Henry J. Franklin

Research Professor in Charge of the Cranberry Station at East Wareham.

Two general bulletins on cranberry insects have been published by the United States Department of Agriculture.[1] Both were based on work done mainly in New Jersey. Cranberry insect problems in Massachusetts vary widely from those in New Jersey, for several of our important pests are nearly or quite unknown in that state and differences in methods of culture and in climate affect the situation greatly in many ways.

The possible value of a paper of this kind may be judged if it is recalled that there are about 14,000 acres under cranberry cultivation in Massachusetts,[2] that this fruit is the leading export crop of the State, with a gross annual value of from $2,600,000 to nearly $5,000,000,[3] and that insects have destroyed on an average fully a fifth of the crop yearly.

It is hoped that this treatise will meet a need that long has been voiced, and it is with the apologies of the Commonwealth that the first paper covering this important feature of cranberry culture is presented only after a lapse of nearly three-quarters of a century since the industry began in this, the state of its origin.

Every effort has been made to arrange this paper so clearly and simply that cranberry growers may find it not only informing but thoroughly usable. It is amply illustrated, and the color plates and tables for the identification of the various species should be particularly helpful. It is divided into six parts, as follows:

Part I.—Worms or wormlike forms attacking the foliage, buds, flowers or fruit.

Part II.—Forms not wormlike attacking the foliage or fruit.

Part III.—Insects attacking the stem.

Part. IV.—Insects attacking the roots.

These four parts briefly describe the various pests, their life histories, and the injuries they do, and give the controls found most effective.

Part V.—Insects and other animals beneficial to cranberry growing.

Cranberry flower pollination is treated here, and the predatory enemies and insect parasites of cranberry pests are discussed.

Part VI.—Insecticides and paraphernalia used in fighting cranberry pests.

Spraying apparatus, the insect net, and insecticides are discussed here.

This bulletin presents Part I, the other five parts being held for another bulletin.

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[1] U. S. Dept. Agr. Farmers' Bul. 178, by J. B. Smith (1903); and
U. S. Dept. Agr. Farmers' Bul. 860, by H. B. Scammell (1917).

[2] Mainly in Plymouth, Barnstable and Bristol counties, but also in five others.

[3] This averaging for the last six years as great as tnat of the State's potato crop and considerably over half as great as that of the commercial apple crop of all New England.

PART I.—WORMS OR WORMLIKE FORMS ATTACKING THE FOLIAGE, BUDS, FLOWERS OR FRUIT.

This section embraces a majority of the cranberry pests. The worms may be classified as follows:

Classification Table.

	With much hair covering most of the body	hairy worms (p. 49).
	Without much hair	1
1.	Either legless or working only inside the berries—miscellaneous pests	(p. 54).
	With legs and not confined to working in the fruit	2
2.	With the habit of sewing the leaves together with silk	fireworms (p. 5).
	Not sewing the leaves together	3
3.	The hind half of the body with only four legs	spanworms (p. 37).
	The hind half with more than four legs	4
4.	With a prominent sharp horn on the back near the hind end	apple sphinx[4].
	With no such horn	5
5.	Green, without stripes along the sides	cranberry sawfly (p. 66).
	Not green, or, if green, with noticeable side stripes	cutworms (p. 21).

FIREWORMS.

These are relatively small worms and they wriggle vigorously when disturbed, moving forward or backward with equal celerity. They sew together with silk the leaves among which they feed and so form nests to protect themselves from parasites and other foes. They usually begin this webbing soon after they hatch, by sewing together three or four leaves at the tip of a single upright as shown in fig. 8. The later webbing varies somewhat but usually draws several uprights together finally. The worms often injure the foliage so that it turns brown and looks as though a fire had burned the vines—hence the name *fireworm.*

Four kinds of fireworms do material harm on Cape Cod bogs. They may be distinguished as follows:

Table of Worms.

	Head black	black-headed fireworm (p. 6).
	Head not black	1
1.	Body with conspicuous white spots along the back and sides	spotted fireworm (p. 19).
	Body without such spots	2
2.	Body with dull reddish lines along the back and sides	red-striped fireworm (p. 16).
	Body pale yellowish, without reddish lines	yellow-headed fireworm (p. 12).

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[4] *Sphinx gordius* Cram. These caterpillars grow to be about two and a quarter inches long. As they mature they are smooth and green, but sometimes strongly shaded with pink or purple, with seven parallel stripes slanting downward forward on each side, each composed of a red line bordered above with rather deep brown and below with white. They are ornamented also with many minute brown circles. They mature in late July, August and September, and cranberry pickers often find them in their scoops. They never do much harm. The gray moths expand three inches or more and are not uncommon on the bogs in late May and June.

Black-Headed Fireworm.[5]

If we consider all the cranberry growing sections of the country, this is the most harmful cranberry insect, and in Massachusetts the fruit worm alone has done more damage. Means of control, however, have now developed so that much injury by it suggests poor management.

On Cape Cod, this insect never harms seriously a bog that has not been flooded during the winter, and its infestations cling more tenaciously to large compact bogs than to small areas. The water kills or drives ashore its enemies, such as spiders and parasites, and protects its eggs from winter adversities. The foes of the pest are, of course, slower in again reaching the center of a large compact bog in effective numbers than they are in reaching that of a small one. So an infestation developing on a large bog always gets serious on the middle part first.

Distribution and Food Plants.

This fireworm is very destructive in Massachusetts, New Jersey, and Wisconsin and on Long Island and the coast of Oregon and Washington.[6] It has been found in Maine, California and Canada. It is not known to feed on anything but cranberry.[7] It generally attacks Howes vines more than Early Black.

Character of Injury.

The newly hatched worm of the first brood usually begins by burrowing into the under side of an old leaf, the new growth of the season not yet having put out at all, and works as a leaf miner, casting out on the lower surface a small mass of refuse (fig. 1). An area on the upper side immediately over these castings is much lighter colored than the rest of the leaf, and the first hatching of the insect often may be detected most easily by these light patches.

If the hatching begins early, the young worms, on leaving their mines in the old leaves, mine the terminal buds just as they are swelling to start new growth, and sometimes ruin most of them before being discovered.

As new shoots appear, the worms proceed to sew three or four of their tip leaves together. If the worms hatch after the new growth develops, they usually go directly to the new tips without mining the old leaves. The webbed tips generally are the first work noticed by growers (fig. 2).

The worm usually leaves the tip it has sewed up within a few days and either webs leaves farther down on the shoot or goes to another upright the new growth of which it sews up, commonly webbing in one or more other uprights. If the worms are very abundant, two or three often work together and include several uprights in their nest (fig. 3). They feed freely on the new leaves and flower buds in their nests, often destroying the whole crop prospect and turning the bog brown.

During the interval between the two broods the vines put forth more new growth and recover considerably from their injury.

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[5] *Rhopobota vacciniana* (Pack.). The writer is not convinced that this species is the same as the European holly feeder, *R. naevana* (Hubner), and hesitates to follow Heinrich in this (cf. U. S. Dept. Agr. Bul. 1032, p. 45, 1922). Dr. J. McDunnough seriously questions Heinrich's conclusion.

[6] Only on the Pacific coast does this fireworm thrive generally on bogs not flooded during winter.

[7] *Vaccinium macrocarpon* Ait. and *V. Oxycoccus* L.

The work of the second brood varies more than that of the first. It may be more severe or less severe, depending on how much the hatching is suppressed and how freely the worms die of disease. If the hatching begins while the vines are in flower, the small worms may work mostly in the blossoms, especially in the ovaries which they excavate to form tiny cups, and web the foliage only in their later stages. Usually they go to the tips when they hatch and sew the leaves together, but this tip-webbing is more gradual than that of the first brood. They usually web together several uprights at last and may make nests even larger than those of the first brood. Whether they web much or not, they reduce the crop in proportion to the amount of infestation by scoring the berries or working in them somewhat as the fruit worm does. This brood may greatly reduce the crop possibilities for the next year, for the tips of the injured uprights usually fail to form normal fruit buds. Many of the chewed leaves soon drop and the vines recover somewhat in the fall, mainly by putting out some tip growth, but the uprights are often rather bare.

Description and Seasonal History.

The Egg.

This pest winters in the egg stage, some of the eggs having been laid by second-brood moths and some by first-brood moths, the hatching of the latter having been suppressed. The eggs (figs. 4 and 5) are very flat, disklike, light yellow, and about a thirty-second of an inch in longest diameter. They are laid singly, nearly always on the backs of the leaves of the new growth. Often several are placed on one leaf. The leaves of delicate uprights deep among the vines generally have more than their share.

Most of the eggs on the leaves in late fall often vanish while under the winter flood, and they evidently perish when they disappear in this way, for the infestation always is reduced the next spring when this happens. Usually, however, most of the eggs stick to the leaves until spring and hatch. If an infested bog is left unflooded for the winter and the vines are winterkilled, the dead leaves drop in the spring and the fireworm eggs on them usually dry up and fail to hatch.

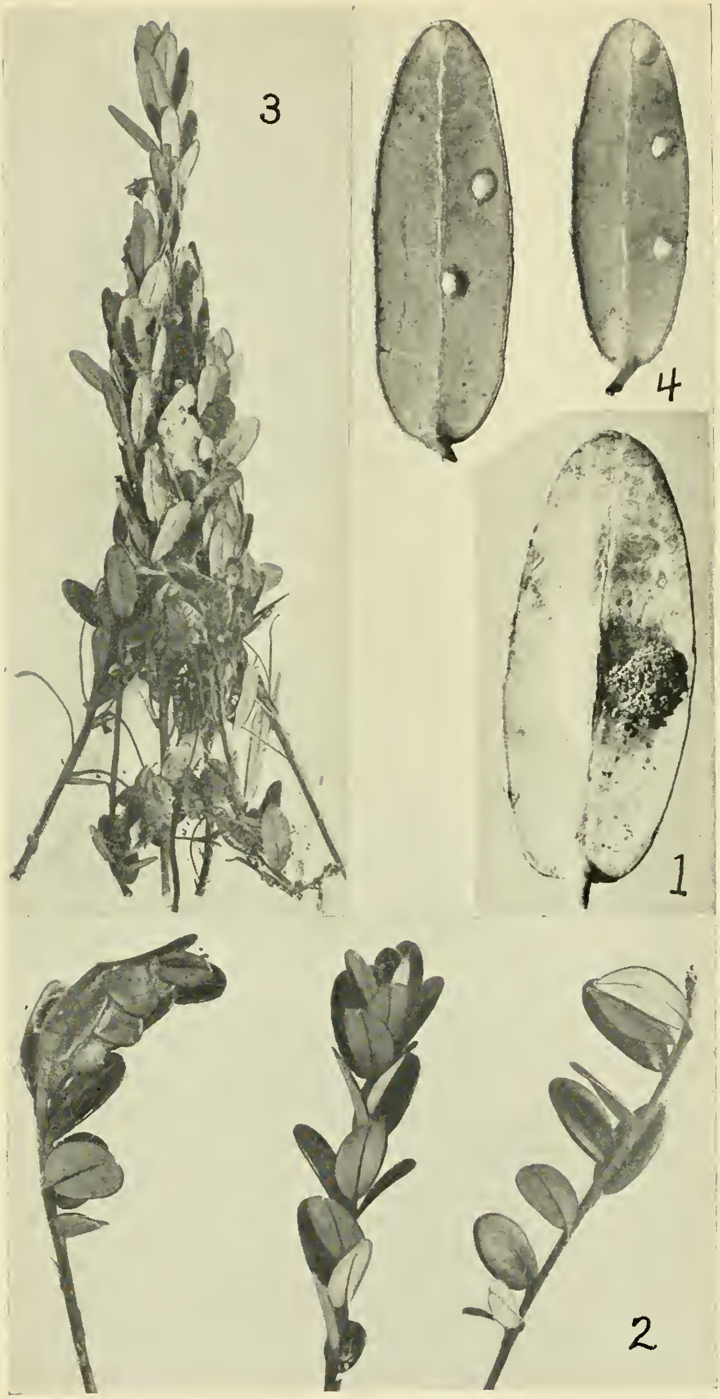
Hatching sometimes starts the first week in May and occasionally is delayed, even on bogs drained of the winter flowage early in April, until the first of June; but normally it begins about the middle of May. The hatching period often lasts but three weeks on thinly vined bogs if the weather is warm, but it may continue six weeks among rank vines in cool weather.

The black head of the worm may be seen through the shell for a day or two before hatching occurs. When the worm emerges, the eggshell is left as a thin shiny whitish scale on the leaf.

The first brood of moths lay their eggs in late June and July. Many of these eggs do not hatch till the next spring. Because of this, the hatching period of the second brood of worms on any given bog often lasts little more than a week. If the winter water is held till late May, the deferment of the hatching of this brood is very often practically complete.

The Worm.

The worm (fig. 6) is greenish or pale yellowish with a shining black head and neck, and is about a third of an inch long when full-grown. First-brood



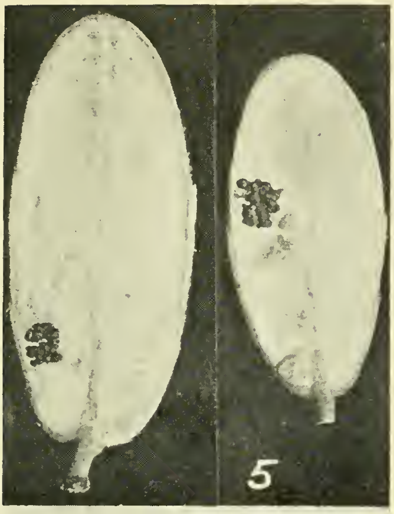
Black-headed Fireworm.

Fig. 1. Cranberry leaf with pile of castings over mine of newly hatched worm. Much enlarged.

Fig. 2. In middle, uninfested cranberry upright; at right, upright with the first webbing; at left, more advanced webbing.

Fig. 3. Nest of webbed cranberry uprights.

Fig. 4. Eggs on backs of cranberry leaves. Much enlarged.



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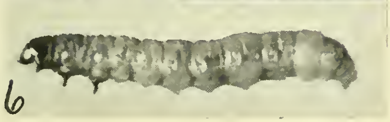

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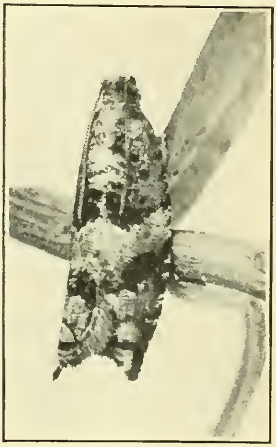

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Black-headed Fireworm.

Fig. 5. Cranberry leaves with fruiting bodies of a fungus (Venturia compacta Pk.) often mistaken by growers for its eggs. Much enlarged.
Fig. 6. Larva. Considerably enlarged.
Fig. 7. Moth. Much enlarged. (From U. S. Dept. Agr. Farmers' Bul. 860.)

worms generally take nearly three weeks to mature, but those of the second brood mature in about two weeks. The second brood sometimes works till well into August, even on bogs bared of the winter water in April.

The Pupa.

In Massachusetts and New Jersey the mature worms generally leave the vines to pupate on the sand or in the trash beneath them. The pupa often is naked but usually is in a light case of silk and sand or fallen leaves. If water happens to be standing under the vines, the worms all pupate among the webbed foliage. They generally do this in Wisconsin, probably because most of the bogs there are poorly drained. The pupa is light brown at first, but it gets almost black before the moth emerges. The pupal period of the first brood is nearly two weeks, and that of the second about a week and a half.

The Moth.

The moth (fig. 7 and Plate One, fig. 6) is dark grayish brown and so small that it often is mistaken for a fly when in flight. It expands somewhat over three-eighths of an inch. The fore wings are marked with gray-brown and silver-gray bands. The female may lay eggs within a day after it emerges. The moths fly little during the day unless it is warm and very cloudy, but they are flushed up easily. At dusk they fly and hover freely just above the vines.

Treatment.

Cessation of Flooding.

If a badly infested bog is not flooded at all for three years it generally becomes free of this pest, and sometimes it will do so in a year. This treatment is not advocated because of the danger of winterkilling and of a great increase of fruit-worm infestation.

Reflowing.

Complete flooding early in June has been long the standard control for the first brood. It also cleans bogs of several other pests. It is often very satisfactory, but it must be done with a careful allowance for the factors that cause the injury which often attends it and may destroy all prospects of a crop. The vines are less likely to be hurt if the weather and water are clear while the water is on, for strong sunlight is necessary to the process of photosynthesis by which the plants tend to maintain a normal supply of oxygen in the water. A too-prolonged lack of sufficient oxygen is the main cause of flooding injury. Cloudiness with a high water temperature is especially dangerous, for the warmer the water the faster the plants respire and the greater their need of oxygen. A rise in temperature of 18°F. doubles their rate of respiration. The floral parts and growing tips respire much faster than other parts of the vines and so are hurt most easily by flooding. Water from swamp reservoirs is more likely to do harm than that from ponds or streams, for it usually has much less oxygen to begin with. The conditions of weather and water which injure the vines quickest also kill fireworms most readily.

The factors affecting the results of this flooding vary so that it is hard to make rules for the operation. The following table may be a fair guide in clear weather with water from a clean pond or stream.

Highest Temperature reached by Water at Tops of Vines During Flood (degrees F.).	Time Complete Flood should be held (hours).
65	50
70	44
75	38
80	31
85	24

If it gets cloudy or the water is dark and from a swamp reservoir, the time should be 8 to 24 hours according to circumstances. If the weather is very warm, this reflow should be put on in the night if possible and also taken off at night, for if tender, growing vines stand in water under a hot sun long they may scald. This flooding must be done before the blossoms begin to open much. If the winter water has been let off before May 8, June 7 is usually about the right date.

It has been found lately that this early summer reflow much promotes the infection of the new growth with the fungi of some of the worst putrefactive cranberry diseases. Because of this and of the danger of injury attending its application, the treatment is less approved than formerly. However, as it greatly checks[8] the spread of the false blossom disease, while it is not certain that any spray will do this, it seems advisable where this disease is present.

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[8] Probably indirectly.

Reflooding before most of the eggs hatch (say about May 25), if not followed by a later treatment, tends to make an infestation worse, for it interferes with the progress of spiders and parasites onto the bog.

Late Holding of the Winter Flood.

If the winter flowage is held late[9] and shallow and the weather is warm, many of the eggs hatch under the water and the worms drown. If held till August, it kills all the eggs that are under water and fail to hatch, but it also cuts off the season's crop and often so injures the vines that it takes them a year or two to recover.

Any holding of the winter flood after about May 10 generally tends to control this insect by shortening its active season and thus increasing the suppression of the second brood. If it is held till May 25, the chances are nearly even that this brood will be suppressed entirely. Where water supplies are limited, advantage should be taken of this more generally than it has been. Probably it is best to hold the winter water on most such bogs till May 22 rather regularly,[10] and also spray as recommended below. Besides helping to control the fireworm such late holding of the winter flood keeps the vines in condition to resist frost till about June 1, much improves the keeping quality of the fruit, controls the false armyworm and largely checks the fruit worm and gypsy moth.

A good treatment for serious infestations on large bogs is to bunch the hatching of the eggs by holding the winter flood till June 1, and reflood three weeks later. This generally cleans out the fireworm well, but reduces the season's crop.

Spraying.

The following is a standard spray for this pest on the Cape:[11]

40 per cent nicotine sulfate	1 quart
Fish-oil soap	4 or 5 pounds
Water	100 gallons

It should be used against the first brood from one to four times according to circumstances, and against the second brood once or twice depending on how much the hatching is suppressed. This spray never harms the leaves or blossom buds, but it often blasts the flowers and small berries. If the soap is left out, however, it is safe to use during and after the bloom. It is a bit less effective without soap, but this may be made up for somewhat by adding 6 pounds of dry lead arsenate. It must be applied thoroughly and in sufficient quantity not only to wet completely the tops of the vines but to penetrate the tips webbed by the worms. Three hundred gallons or more to the acre should be used for each application.

The second brood must be treated as soon as hatching is general, usually five or six days after the first worms appear, for the following reasons: (1)

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[9] Till late May or later.

[10] Such late holding is generally advisable only on mature bogs that are completely flooded with less than 18 inches of water.

[11] Since this bulletin was written, a new spray, sodium oleate-oleoresin of pyrethrum, has been found so effective in controlling the various fireworms and cranberry spanworms and leafhoppers that it promises largely to displace nicotine sulfate as a cranberry insecticide. Unfortunately, this material has not yet been standardized, so the advisability of its use is curtailed somewhat for the present. More extensive experience with it is necessary before an adequate discussion of its use is possible. It should be used in concentrated form with sodium silicate added, apparently at the rate of a pound in about fifteen gallons of water.

Because of its partial suppression, this brood usually is well bunched in hatching; (2) the worms are killed most easily when small; (3) if treatment is delayed, the worms may injure the tips so that they will not bud well for the next year; and (4) the worms that enter berries cannot be reached with a spray.

A half-effective spraying with nicotine sulfate for a moderate infestation sometimes may do almost as much harm as good, for it affects the worms less than their much more exposed natural enemies.

Outbreaks of a disease[12] sometimes wipe out the second brood on many bogs. If spraying is contemplated or in progress, it is well to watch for this, for the epidemic may make treatment unnecessary. The general abundance of the fungus that causes it may be learned by leaving fifty of the worms in a moist chamber[13] over night. By morning it will appear on most of the diseased ones as a fluffy white mold, and around them as a ring of white spore dust. Prof. W. H. Sawyer, Jr., has found this fungus absent or inactive on the bogs with fireworm infestations notably resistant to control but generally abundant on other infested areas. He has found further that the bogs on which it is scarce are generally large, well-managed areas that have been flooded, sprayed and resanded regularly. Evidently it is killed out, directly or indirectly, by late-spring or summer flooding or by spraying or sanding, for no evidence has been found that fall flooding or the winter flood, even when it is held late, affects it. If, as the writer suspects, the early-summer flooding is responsible, this should not be preferred to spraying as a treatment for insects except possibly on bogs with false blossom. The fungus passes the winter in the form of resistant spores among the chaff on the bog floor.

Moderate infestations of this fireworm must be treated as though they were severe. Even slight ones should be given due attention, especially on large bogs. They should be treated at least once during the season.

Yellow-headed Fireworm.[14]

This pest never harms bogs that are flooded completely during the winter on Cape Cod and seldom does elsewhere, for the wintering moths cannot endure submergence. It is attacked by parasites much more than the black-headed fireworm. They do not reduce the first brood much, but they decimate the second so that, however severe the infestation, the first brood of the next year never does much harm. There are two broods in Massachusetts, three in Iowa and Wisconsin, and three and sometimes four in New Jersey.

Distribution and Food Plants.

This fireworm is known widely as an apple pest throughout the United States and southern Canada. It also feeds on huckleberry, swamp blueberry,[15] glaucous willow,[16] and sweet gale.[17] As a cranberry pest it is worse in New Jersey than elsewhere. It is much less generally destructive on the Cape than the black-headed fireworm.

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[12] Caused by *Entomophthora sphaerosperma* Fres. This fungus also attacks other insect species. Prof. Sawyer has grown it abundantly on various culture media. This seems to have been the first really successful culturing of a fungus of this genus. Prof. Sawyer is doing his field work on this disease in co-operation with the Cranberry Station at East Wareham and studying it further in the Laboratories of Cryptogamic Botany at Harvard University. He is examining carefully the possibilities of controlling this fireworm by distributing the culture-grown fungus in a spray or otherwise.

[13] A clear smooth tumbler inverted over a glass plate and containing a little moist cotton is handy for this.

[14] *Peronea minuta* (Rob.).

[15] *Vaccinium corymbosum* L.

Character of Injury.

The small worms of the first brood feed on the old leaves at first, usually sewing the surfaces of two adjacent ones together and working between them. Otherwise this species works much like the black-headed fireworm (fig. 8), but it tends to gather more uprights into its web (fig. 9) and often does more intensive injury, not only browning the bog but often leaving only bare uprights in the fall. The worms work in the berries and score them as black-headed fireworms do (fig. 10).

Description and Seasonal History.

The moths that appear in the fall (Plate One, fig. 4) are reddish gray, but they gradually lose the red tinge and become slate color. They are small but considerably larger than those of the black-headed fireworm. They winter on the bog and surrounding upland, hidden in the vines or other shelter, but fly on warm days. They lay during April. The eggs look like those of the black-headed fireworm and are laid singly, mostly on the backs of the leaves. They hatch during the first half of May.

Newly hatched worms of the first brood usually have dark heads but they soon change and commonly are distinguished from black-headed fireworms by the yellow color of the head. The body is pale yellowish. The mature worms are about half an inch long (fig. 11). They pupate in silken cells among the webbed uprights, mostly early in June.

The pupa is light brown at first, but it grows blackish as the moth develops. It is from a quarter to nearly a third of an inch long and has a prominent and distinctive knob at its head end (fig. 12).

The summer moths appear late in June and fly about three weeks. They are clear orange (Plate One, fig. 5), but otherwise like those of the winter brood. They may be flushed up in clouds on badly infested bogs. They lay eggs during most of their flight and generally disappear about July 10. The eggs usually begin to hatch about July 8 to 10. The worms continue to appear for some time and develop more slowly than the first brood, some of them not maturing till early September. They pupate like the first brood, the pupal stage lasting about a month, and the gray winter moths appear in September and early October.

Treatment.

Complete winter flooding, especially if the water is held till May, is a sure control.

Spraying with 6 pounds of dry lead arsenate in 100 gallons of water is very effective. It should be done for the first brood about May 24, and for the second about July 10. The first-brood treatment will check the gypsy moth also if that insect threatens. A single spraying, well timed for either brood, should be enough for a whole season and often will control the pest for two or

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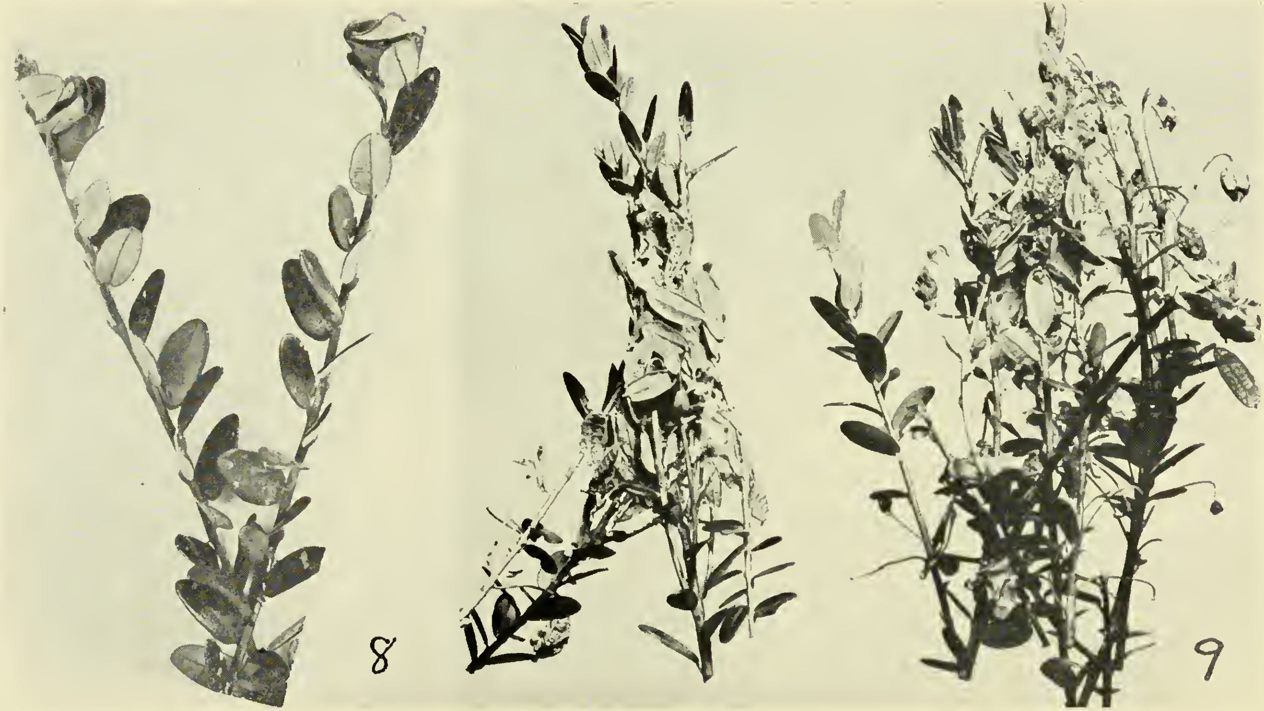
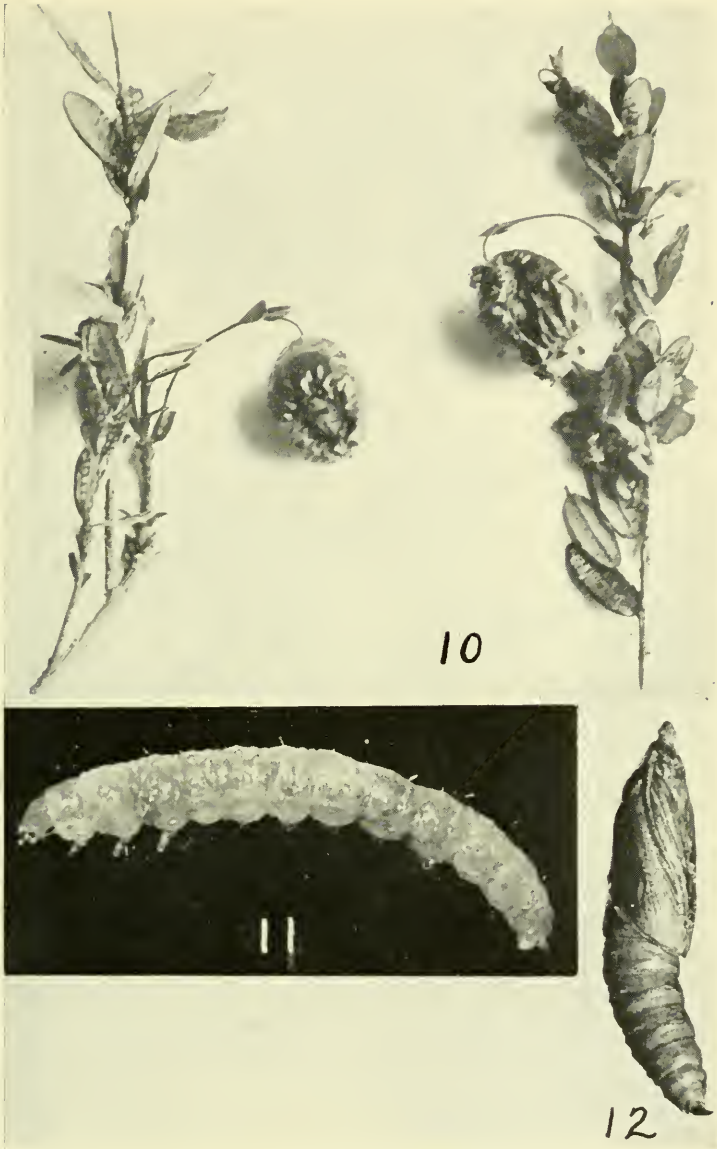
[16] *Salix discolor* Muhl.
[17] *Myrica gale* L.



Yellow-headed Fireworm.
Fig. 8. Cranberry uprights with tips webbed by young worms.
Fig. 9. Nests of webbed cranberry uprights.



Yellow-headed Fireworm.

Fig. 10. Work on berries.
Fig. 11. Caterpillar. Much enlarged.
Fig. 12. Pupa. Much enlarged.

three years, for its parasites generally need only occasional help to keep it down.

The moths may be killed early in April with a spray of 1 quart of 40 per cent nicotine sulfate and 4 pounds of fish-oil soap in 100 gallons of water.[18] This treatment is advisable if there is no prospect of much gypsy moth infestation, for it will save spraying in the growing season with its mechanical injury to the vines. This spray will kill the worms too, and it should be applied about June 6 if earlier treatment has been neglected, and the bog also has a large spittle-insect or leafhopper infestation.

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[18] See note 11, p. 11.

Red-striped Fireworm.[19]

This insect never harms bogs that are flooded completely during the winter. It is much less important than either of the fireworms already discussed, but it occasionally develops a severe infestation on a dry bog. It sometimes works with the yellow-headed fireworm.

Description and Food Plants.

This New Jersey and Massachusetts pest has not been recorded as harming bogs elsewhere. It ranges from Maine to Virginia and western Texas. Swamp blueberry and dwarf blueberry[20] are its favorite food plants. They usually harbor large numbers of the worms in the fall everywhere in the eastern part of the State. It also attacks deerberry[21], low blueberry[22], dangleberry[23], black huckleberry[24], male berry[25], fetter bush[26], and leather leaf[27].

Character of Injury.

Some of the newly hatched worms go directly to the tips of the new growth, but many first mine the basal part of the blade of the old leaf between which and the stem the egg was held, entering it from the upper surface and covering the entrance with a mass of green castings (figs. 13 and 14).

The webbing begins among the terminal leaves but is not very conspicuous there. As the season advances it is extended farther and farther down the shoot and often two or three uprights are sewed together (fig. 15). This species webs its nests more closely than the other fireworms do, and forms in them a characteristic irregular tubular case of silk covered with brown castings (fig. 16). The worms are parasitized considerably, but their nests are a far better protection than those of other fireworms and they keep much more concealed in them.

Description and Seasonal History.

Most of the worms leave their cases during late September and October and go down into the trash and surface sand of the bog floor to remain dormant until the next spring. A few remain in their nests, many of which break off and drop during the winter. They pupate one after another during most of May and June. The moths usually appear from soon after mid-May until into August, those found toward the last being adults of a second brood.

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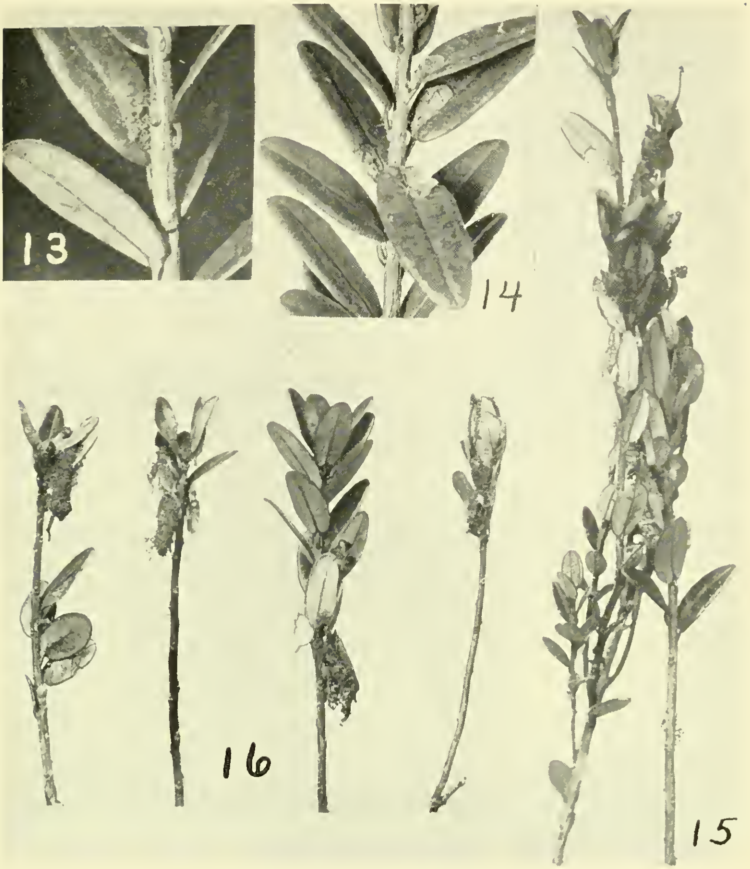
[19] *Gelechia trialbamaculella* Cham.
[20] *Vaccinium pennsylvanicum* Lam.
[21] *Vaccinium stamineum* L.
[22] *Vaccinium vacillans* Kalm.
[23] *Gaylussacia frondosa* (L.) T. & G.
[24] *Gaylussacia baccata* (Wang.) C. Koch.
[25] *Lyonia ligustrina* (L.) DC.
[26] *Leucothoe racemosa* (L.) Gray.
[27] *Chamaedaphne calyculata* (L.) Moench.



Red-striped Fireworm.

Fig. 13. Mine of young worm covered with castings.
Fig. 14. Cranberry leaves mined at base by newly hatched worms, with castings removed.
Fig. 15. Nest of webbed cranberry uprights.
Fig. 16. Cranberry uprights with tubular cases made by worms in webbed nests.

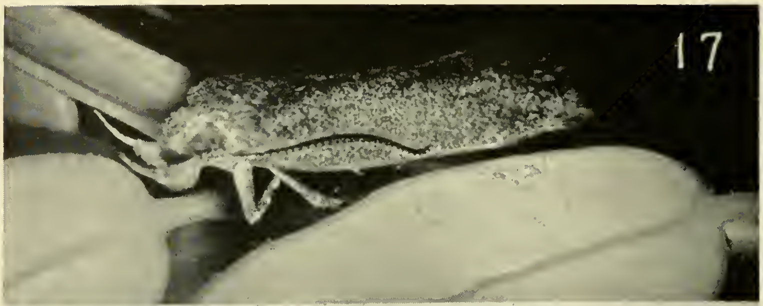
The Moth.

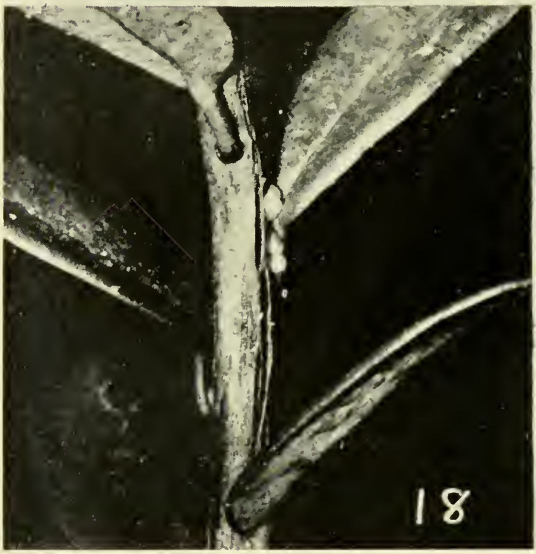
The adult is mostly dark brown, but has a white face, large rusty palpi, a few white dots on the fore wings and white spots on the legs (fig. 17 and Plate One, fig. 3). It expands about nine-sixteenths of an inch.

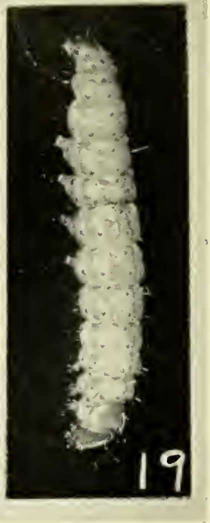
These moths usually keep quiet among the vines during the day, but they flush fairly easily. They have a darting flight and hide even more nimbly than those of other fireworms, often going into the litter under the vines when pursued.

The Egg.

The moths lay eggs from late May to early August, the second brood laying toward the last.







Red-striped Fireworm.

Fig. 17. Moth. Much enlarged.
Fig. 18. Cranberry upright with eggs between stem and base of leaf. Much enlarged.
Fig. 19. Larva. Considerably enlarged.

The eggs are irregularly ellipsoid and about a fortieth of an inch long. They are very plastic and pearl white when laid, but turn pinkish or yellowish before hatching. They usually are wedged in between the vine and the petiole or the base of the blade of a leaf (fig. 18), or are placed among the bracts of an opening terminal bud, but are deposited also under loose bark. They usually hatch from mid-June to mid-August, the egg stage lasting about sixteen days in early June and about nine in late July.

The Worm.

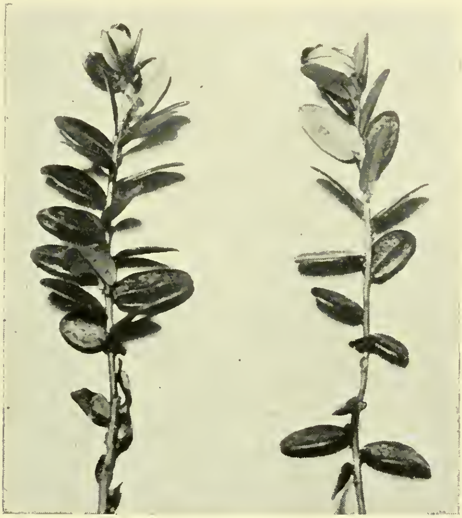
The newly hatched larva is pale greenish yellow, with the head and cervical shield brown. As it grows its head becomes yellowish, and dull reddish lines appear running the length of the back and sides. The mature worm (fig. 19) is fully three-eighths of an inch long and is more slender and agile than other fireworms.

All the worms that hatch in June pupate in their nests after mid-July, the moths emerging at the end of July and early in August. Most of those that hatch after the first of July continue as worms till the following May as already noted. The insect is therefore partly one-brooded and partly two-brooded.

Treatment.

Spraying with 6 pounds of dry lead arsenate to 100 gallons of water is effective, but three applications (about June 22, July 10 and July 28) are necessary because of the long hatching period of the insect.

One thorough application, about August 6, of the nicotine sulfate and soap spray advocated for the black-headed fireworm will eradicate this pest.



Spotted Fireworm.

Fig. 20. Cranberry uprights with tips webbed by young worms.

Spotted Fireworm.[28]

This is the least important of our four fireworms. It works mainly on dry bogs, never infesting those that are reflooded regularly. It works like the yellow-headed fireworm (fig. 20), but sews even more uprights into its nest. It sometimes does considerable injury but never browns a bog.

Distribution and Food Plants.

This species has been found in Maine, Massachusetts, New Jersey, New York, Illinois, Wisconsin, Minnesota and Canada. It has been recorded as a cranberry feeder in Massachusetts, Minnesota, New Jersey and Wisconsin[29]. It also attacks loosestrife[30], sweet melilot, willow and aster.

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[28] *Cacoecia parallela* (Rob.).

Description and Seasonal History.

The Worm.

The worms are seen on the bogs first in early June. They mature in late June or early July and pupate in early or mid-July. The moths emerge during the last half of July or early in August. They lay their eggs late in July and early in August. The eggs hatch in about ten days. The worms grow slowly and are found in steadily decreasing numbers until the first of September when the last disappear. They are less than a third grown when they thus vanish. They may hide in trash on the bog floor to winter.

The small worms are yellowish white with brown heads. As they grow, the head becomes amber and the body for a time may be somewhat reddish. As they mature (Plate One, fig. 7), the head changes to rather light reddish brown and the body becomes more or less olive green on the back and sides, with conspicuous and somewhat elevated white spots along the whole length, and usually one pale hair rising from each spot. They grow to be fully three-quarters of an inch long and pupate among the webbed uprights.

The Pupa.

The pupa squirms vigorously when disturbed. It is about half an inch long and mostly chestnut brown, but its back is somewhat darker, being almost black toward the front. There is a prominent transverse ridge at the head end and several rows of small backwardly directed teeth run across the top of the abdomen.

The Moth.

The moth (Plate One, fig. 1) expands about three-fourths of an inch. It is brown with two chocolate-colored stripes crossing each fore wing diagonally, one near the middle and the other shading the tip.

The Egg.

The eggs are minute, circular, and flat and partly overlap one another, being laid in flat shiny masses of 100 to 150. They are lemon yellow at first but later become orange, and as they near hatching the brown bands of the worms show plainly through the shells.

Treatment.

The worms seldom are noticed much before they mature and as they rarely do serious harm it seldom pays to treat them. The nicotine and soap spray advocated for the black-headed fireworm, applied thoroughly, will kill them.

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29. Hardenberg's "Oblique-banded roller (*Archips* species)" was pretty certainly this species (See Wis. Agr. Expt. Sta. Bul. 159, p. 15, 190[illegible]).

30. *Lysimachia* sp.

CUTWORMS.

These worms feed openly, never webbing the vines. They are one and a half to two inches long when mature, and without noticeable hair. They feed mostly at night, usually hiding during the day among the vines or in the litter on the bog floor or under pieces of board if such are present. They all belong to the same family and, except for differences in coloration, are much like garden cutworms. Most of them are common pests of other crops. All but the false armyworm do injury out of all proportion to the amount of their eating by cutting off flower buds, flowers, small berries or leaves and dropping them to the ground. The green leaves fallen on the water in the bog ditches are often the first sign of their work observed. The moths of all but the blossom worm ordinarily are night-fliers and seldom seen. They measure an inch and a half or more across their outspread wings. Their eggs (fig. 23) are round, slightly flattened, and marked with many ridges radiating from the summit. The worms generally are severely parasitized.

These insects, except the false armyworm and the blossom worm, rarely attack cranberry bogs much unless the winter flowage has been held until the last of May or later[31]. This may be due to one or both of the two following possible causes, the first being the more likely[32]:

1. The moths seem to prefer to lay their eggs on or over damp earth. Bogs drained during the flight of the moths therefore probably invite infestation.
2. By breeding on freshly drained areas the insects may escape their natural foes largely and so develop as they could not otherwise.

The chances are two to one that some of these worms will infest a bog if the winter flood is held till June. Sometimes two species attack a bog together under such conditions and occasionally one is prevalent on some bogs and another on others. They usually appear about two weeks after the water is let off.

The various species are hard to distinguish for a time after they hatch, all being then mostly whitish or greenish, but they may be identified after they are half-grown by the following:

Table of Worms.

Mostly dark, without definite side stripes .... black cutworm (p. 31).
With a conspicuous stripe along each side 1
1. With a row of two to four angular dark spots on each side of the hind part of the back .... spotted cutworm (p. 28).
Without such spots 2
2. The back reddish brown and not marked with pale yellow dots .... cranberry blossom worm (p. 26).
The back mostly dark, grayish, or green 3
3. Found on a bog bared of its winter water before May 20 .... false armyworm (p. 23).
Found on a bog bared of its winter water after May 20 4
4. With many small round or oval dark tubercles noticeable along the back .... fall armyworm (p. 35).
The back without such tubercles; each leg of the four pairs placed together near and behind the middle of the body striped noticeably across the middle of the outer side with deep brown .... armyworm (p. 32).

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[31] Reflooding for ten days or longer in late May sometimes has the same effect that very late holding of the winter water has. If the winter water is let off and the bog is flooded again within a few days, the reflood should be regarded as a continuation of the winter flood as far as its relations to these cutworms are concerned.

[32] Mass. Agr. Expt. Sta. Bul. 192, p. 133, 1919.

PLATE ONE

Upper Part: Fireworm Moths and Worm.

Fig. 1.—Spotted fireworm moth.
Fig. 2.—Moth of Sparganothis sulfureana (Clem.)
The moth is common on dry bogs. The larva has a yellow head and works as a fireworm but never is plentiful enough to do much harm. It also attacks grape and strawberry.
Fig. 3.—RED-STRIPED FIREWORM* moth.
Fig. 4.—Winter moth of YELLOW-HEADED FIREWORM.
Fig. 5.—Summer moth of YELLOW-HEADED FIREWORM
Fig. 6.—BLACK-HEADED FIREWORM moth.
Fig. 7.—Mature spotted fireworm.

Lower Part: Cutworm Moths.

Figs. 8a and 8b.—BLOSSOM WORM moths, showing variation.
Fig. 9.—Fall armyworm moth.
Fig. 10.—Black cutworm moth.
Fig. 11.—Spotted cutworm moth.
Fig. 12.—ARMYWORM moth.
Fig. 13.—FALSE ARMYWORM moth.

PLATE TWO

Cutworms and Cranberry Shoot showing Rose-Bloom.

Figs. 1a and 1b.—Mature ARMYWORM.
Figs. 2a and 2b.—Mature spotted cutworm.
Figs. 3a and 3b.—Mature BLOSSOM WORM.
Figs. 4a and 4b.—Half-grown BLOSSOM WORM.
Fig. 5.—Mature black cutworm.
Fig. 6.—Rosy shoots caused by rose-bloom.
Figs. 7a, 7b, 7c and 7d.—Mature FALSE ARMYWORM. The last three figures show its variation in coloration.
Figs. 8a and 8b.—Mature fall armyworm.

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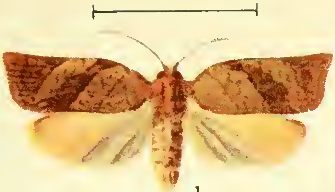
* The names of the more commonly harmful pests are in capitals.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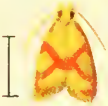
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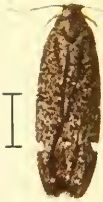
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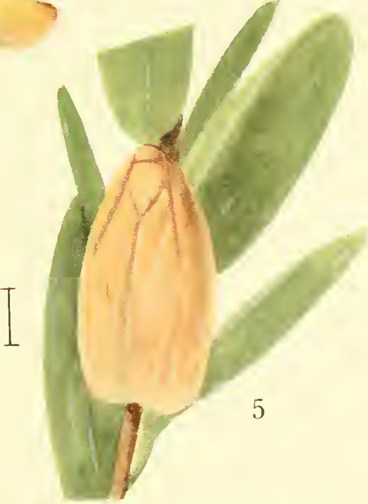
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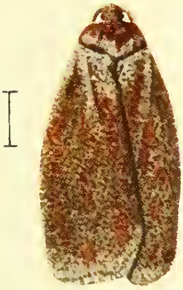
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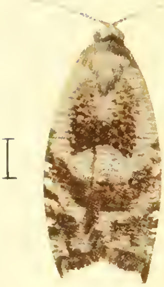
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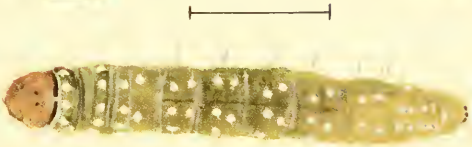
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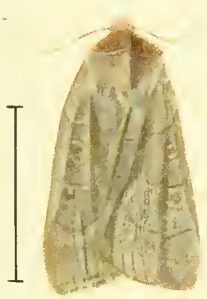
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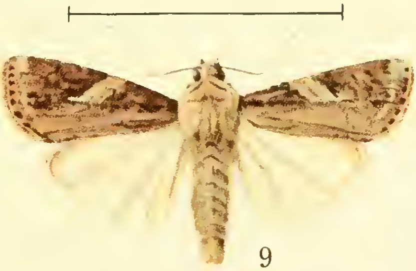
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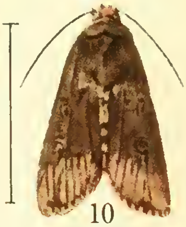
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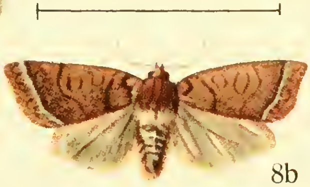
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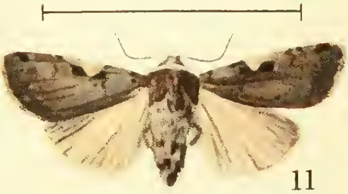
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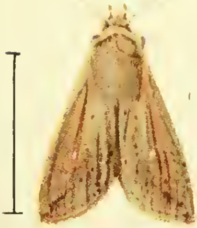
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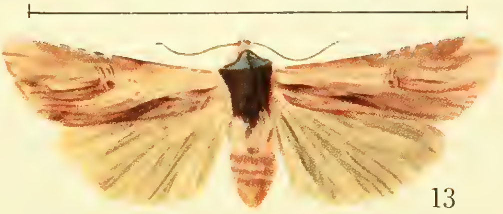
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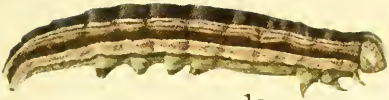
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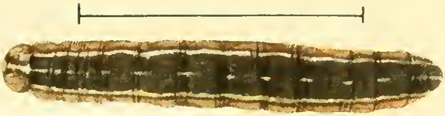
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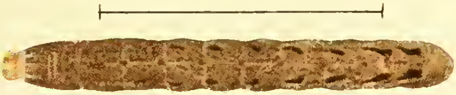
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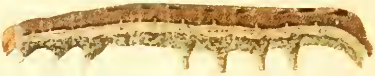
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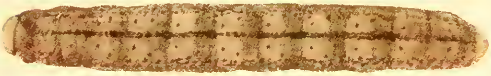
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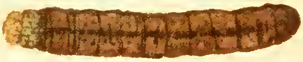
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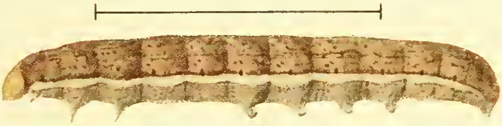
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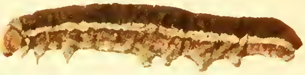
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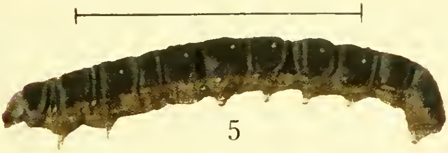
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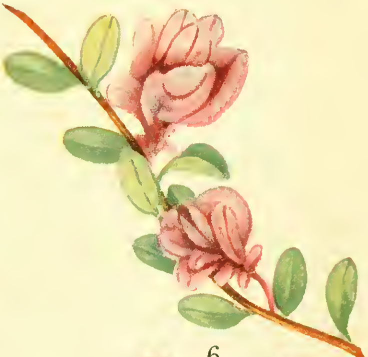
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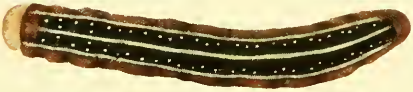
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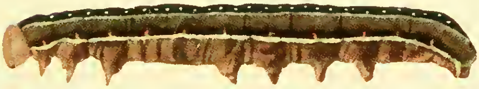
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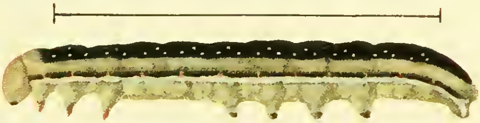
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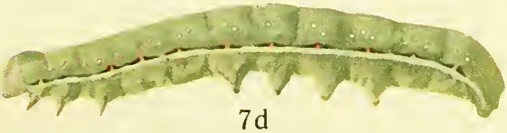
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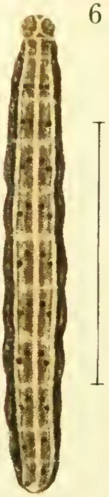
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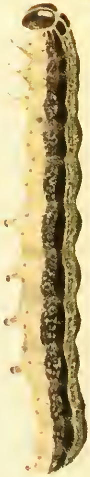
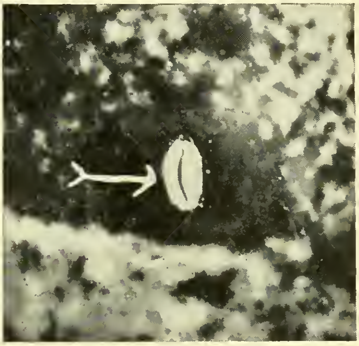

8b

The color of the spiracles helps to distinguish some of these worms in their later stages. The spiracles are the respiratory organs placed at intervals along the sides of the body. They should be examined with a good lens. Those of the armyworm and the black cutworm are blackish, those of the spotted cutworm clear yellowish white rimmed with deep brown (fig. 21), those of the blossom worm reddish brown to dark brown rimmed with dark brown, those of the false armyworm yellowish white in the half-grown stages but deep orange rimmed with deep brown as the worm matures, and those of the fall armyworm pale brown with the rim dark brown.



Spotted Cutworm.

Fig. 21. Spiracle of caterpillar. Much enlarged.

False Armyworm.[33]

This worm is not known as a cranberry feeder elsewhere, but it has attacked Cape Cod bogs for many years and probably ever since the industry began. Some years it is hardly noticed, but sometimes it is one of the more important pests, destroying all prospects of a crop on many bogs if it is not checked. It never infests bogs on which the winter water is held till May 15, and seldom harms strictly dry bogs[34] much.

Distribution and Food Plants.

This insect ranges throughout the northeastern United States and southern Canada, south to the District of Columbia and west to Nebraska and Alberta. It attacks various weeds, grasses, iris, and apple as well as cranberry.

Character of Injury.

The young worms often do great harm by eating out the hearts of the terminal buds (fig. 22) before new growth starts. They develop with the new growth and feed more and more voraciously upon it as they mature, devouring leaves, buds and flowers with equal avidity and sometimes leaving little of the new shoots but the stems, but seldom eating the old foliage much. Their work is more like that of gypsy moth caterpillars than that of any other cranberry pest. They feed freely in the daytime.

Description and Seasonal History.

The Egg.

The moths of both sexes winter[35] and the females lay about 600 eggs apiece in late April and very early May, placing them in masses of sometimes over a hundred on the stems or the backs of the leaves of cranberry uprights (fig. 23). The eggs are whitish at first but soon turn light yellow and later become reddish brown. They are about a thirty-first of an inch in diameter. They hatch during the second and third week of May, the egg stage lasting fifteen to twenty days.

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[33] *Xylena nupera* (Lint.). Heretofore known in cranberry literature as *Calocampa nupera*.

[34] The moths seem to prefer damp locations for egg-laying.

[35] These moths, especially the females, may be caught readily at honey baits on tree trunks about the bogs in the milder nights of April.

The Worm.

The newly hatched worms (fig. 24) are whitish and marked with many black spots each of which bears a slender black spine, these being conspicuous under a lens. They loop much like spanworms but gradually drop this movement. They soon become green with whitish lines along the back and sides, being somewhat darker above than below, and retain this coloration till over a third grown.

The mature caterpillar (Plate Two, figs. 7a, 7b, 7c and 7d) is about two inches long and its head is uniform greenish yellow. Though the arrangement and relative width of the various stripes and lines along the body are the same in all specimens, the general color varies from grass green to dark brown. The stripes are as follows: a broad band of varying color runs the length of the back and is divided in the middle lengthwise by a light line; this band is bordered on each side by a yellowish line; below this line on each side is a much lighter stripe extending nearly down to the spiracles; across the spiracles passes a blackish line which is bordered below by a sulfur yellow one. There are light dots at intervals along the back. The body is greenish or flesh-colored beneath. The spiracles are orange, ringed with deep brown.

The Pupa.

The worms mature in late June and go into the ground to remain dormant two to six weeks before pupating. They pupate mainly in late July and early August. The pupae are stout, about an inch long, and dark brown.

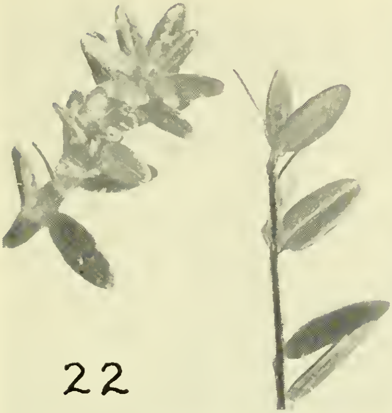
The Moth.

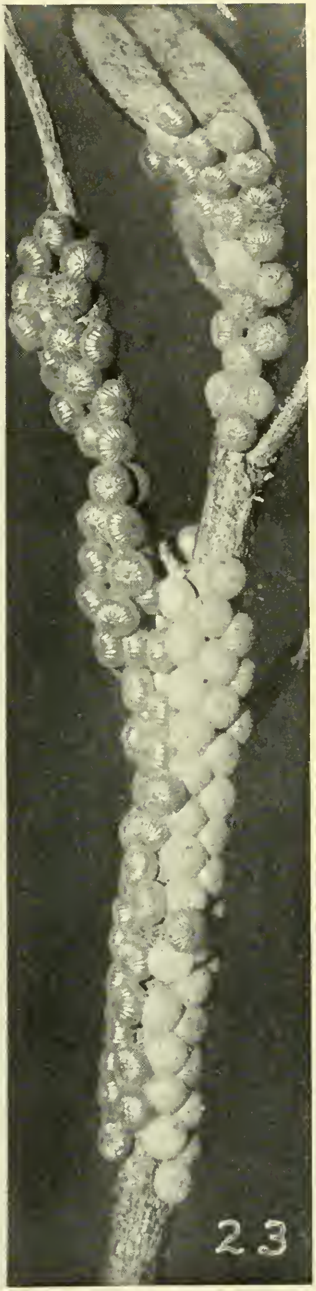
The moths emerge from mid-August till late September. They are (Plate One, fig. 13) light coffee brown with the body reddish sooty brown below and on the back between the wings. The top of the head, the collar, and the abdomen above are pale yellowish brown. The fore wings are variegated, with brown, gray and sooty streaks above and are light brown below. The hind wings are pale brown with a conspicuous dark spot somewhat before the middle and toward the base on the under side. The wings expand two inches or more.

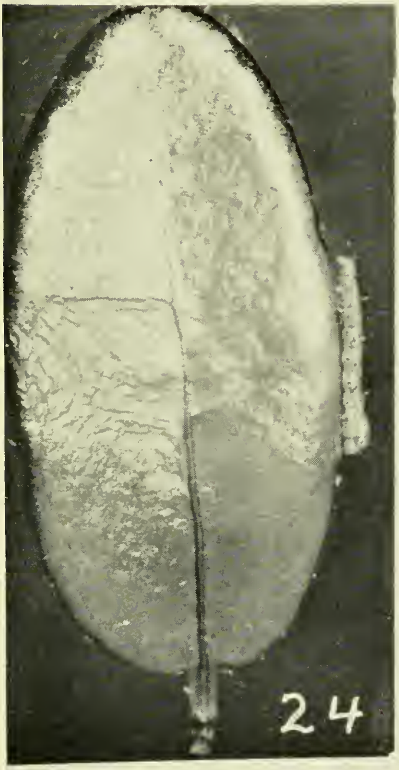
Treatment.

Flooding.

On winter-flowed bogs scant of water for reflooding:—Hold the winter water rather regularly till May 22. This preventive has other advantages. (See p. 11).







False Armyworm.

Fig. 22. Cranberry uprights with terminal buds drilled by young worms.
Fig. 23. Egg-masses. Much enlarged.
Fig. 24. Cranberry leaf with newly hatched worm. Much enlarged.

On bogs bared of the winter water early and with plentiful water supplies:

If the net count (p. 3) calls for it, flood about May 18 for about fifteen hours. If the net count is equivalent to not more than 18 cutworms to 50 sweeps, this treatment may be put off till late May or early June when it will check other pests also, but this is not advocated.

Spraying.

Spraying with 6 pounds of dry lead arsenate in 100 gallons of water in mid-May is effective. It will not check the worms after they are half-grown.

Baiting.

A poisoned bait should be used to reduce serious infestations of any of the cutworms discussed in this paper if flooding cannot be done and the worms have grown too large to check by spraying. The formula for its preparation is as follows: Wheat bran, 25 pounds; sodium fluosilicate, 2 pounds; water, enough to moisten. Mix the dry bran and fluosilicate thoroughly with the hands, then add the water gradually and stir till the bait is dampened throughout but not too wet to crumble and spread readily. This amount of material should be broadcasted by hand over an acre just after sunset. The bait is not effective after it gets stale or has been soaked by rain, so a second application three or four days after the first is often advisable.

Cranberry Blossom Worm.[36]

This is a minor cranberry pest in New Jersey and Massachusetts and is not known to harm bogs elsewhere. It often destroys the crop promise entirely on a small area here and there on the Cape. It is confined to bogs not reflooded regularly in late May or June or after picking.

Distribution and Food Plants.

This insect ranges through the Northeastern States from Maine to Illinois. Cranberry is its sole known food plant.

Character of Injury.

The young worms first nibble the leaves, especially at the margin, or bore into the buds and so spoil them for fruit production. As they grow, they nip off the buds and flowers, dropping them to the ground. They rarely cut off the leaves much, differing in this from the spotted cutworm and the armyworm. They work very little in the daytime.

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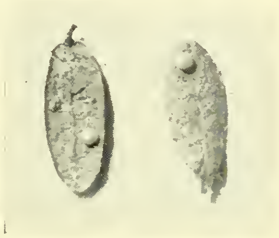
[36] *Epiglaea apiata* (Gr.). Some growers call it "the bud worm."

Description and Seasonal History.

The Egg.

Most of the eggs are laid in October. They are pale yellow at first but soon turn dingy brown. They are fastened singly to fallen leaves (fig. 25) or pieces of dead vine littering the bog floor. They pass the winter, the bog flowage not harming them even when held fairly late. They usually hatch somewhat after the middle of May on bogs drained in April, and in late May or early June where the winter flood has been held till after mid-May.



Cranberry Blossom Worm.

Fig. 25. Eggs on fallen leaves.

The Worm.

The worms (Plate Two, figs. 4a and 4b), after they pass their first stages, are reddish brown, with the head light mottled brown and with a whitish stripe along each side of the smooth and well-rounded body. They mature the last of June on bogs bared of the winter flood early. They then become pale brown, often look somewhat bloated and act torpid and are nearly an inch and a half long (Plate Two, figs. 3a and 3b). They soon enter the ground or deep trash to remain dormant two to four weeks before pupating.

The Pupa.

Pupation normally occurs mostly in late July, usually in a cell slightly below the surface of the ground. The pupa is brown and about five-eighths of an inch long. It is enclosed in a loose and indefinite cocoon of silk and sand. The moths emerge during September and are active till mid-November. Pupation may take place in August or early September and the moths emerge in late September and early October on bogs drained of the winter water late.

The Moth.

The moths vary greatly in color. Some (Plate One, fig. 8a) are brownish gray; others (Plate One, fig. 8b) are fox red above and somewhat lighter below. The front wings are crossed by a few fine lines and there are two characteristic subcircular markings placed lengthwise on the middle of the front part of each. The main part of the body is tufted heavily with hair. The wings expand about an inch and a half. These moths are seen commonly in September and October on infested bogs and on the uplands everywhere. The females are prolific layers. The males fly well and often.

Treatment.

Flooding.

Flood for 18 days right after picking the crop, beginning late in September if possible. This kills the moths and probably any pupae that remain. This treatment has other advantages. (See p. 58).

The flooding late in May advocated for control of the gypsy moth will destroy this pest if the winter water has been let off in April; and the flooding in June for the black-headed fireworm checks it anyway.

Spraying.

A spray of 6 pounds of dry lead arsenate in 100 gallons of water is effective if applied before the worms are half-grown. They grow harder to poison as they mature.

Baiting.

See page 26.

Spotted Cutworm.[37]

This insect has been known to injure occasionally small areas of bog on Cape Cod for over twelve years but has not been reported as a cranberry pest elsewhere. There was a marked outbreak in 1923, two hundred acres or more of bog in various parts of the Cape being so infested as to lose most of the prospective crop, and a few of the worms and scattering marks of their work being found on most bogs.

Distribution and Food Plants.

This cutworm was brought into our country from Eurasia many years ago and now ranges from New England to southern Missouri and the Pacific coast of Oregon and Washington.

It is a very pernicious pest of vegetable and forage crops. The following are some of its food plants: beet, cabbage, celery, chicory, chickweed, clover, corn, cranberry, currant, fern, goldenrod, grass, Helianthus, lettuce, Lobelia, maple, onion, pear, rhubarb, spinach, strawberry, tobacco, tomato, violet and wheat.

Character of Injury.

In 1923, this insect did much harm on a few acres of one bog bared of its winter flood in April. With this exception, it has been known to attack severely only bogs drained of the winter water between May 26 and June 8. It generally works more on Howes vines than on Early Black. The worms work almost entirely at night. They nip off the blossom buds, flowers and small berries, severing the stem near where it joins the ovary (fig. 26), being most active during the blooming. They also excavate partly grown berries (fig. 27) much as katydids do, and cut off many leaves by severing the petiole, apparently eating little of the tissue. The fallen green leaves are seen first in and along the bog ditches and later everywhere under much infested vines. Severe infestations sometimes so defoliate small areas that the bare uprights give the vines a brown tinge at a distance.

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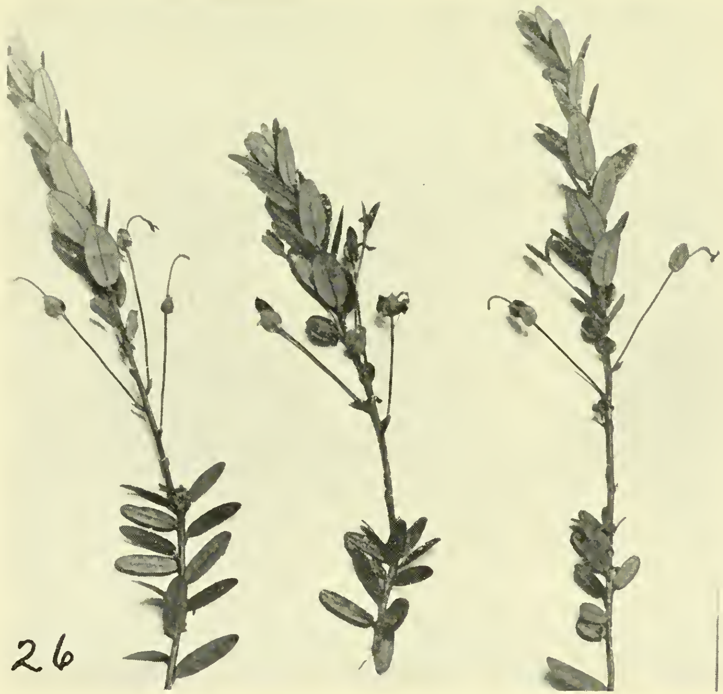
[37] *Agrotis c-nigrum* (L.).



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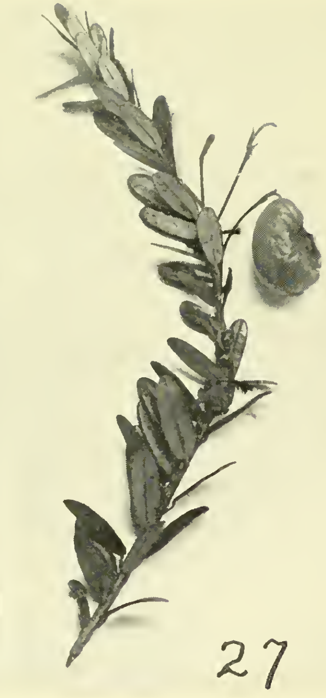

27

Spotted Cutworm.

Fig. 26. Cranberry uprights from which worms have nipped flowers and berries.
Fig. 27. Work of worms.

Description and Seasonal History.

The worms live through the winter and pupate in late April and early May. The moths emerge in late May and early June and soon lay eggs. The worms that hatch from them mature in late July and early August. They pupate in the soil at depths of one to four inches, usually from the last of July to late August. The pupal stage averages about nineteen days, the second brood of moths emerging from mid-August to early September. These moths lay mostly in early September, the eggs hatching in about two weeks to produce the worms that winter.

The Egg.

The eggs are laid in rows or compact masses, one moth laying two hundred or more.

The Worm.

The young worms are pale at first, but they assume their mature coloration before they are half grown. The mature worm (Plate Two, figs. 2a and 2b) is about an inch and a half long and dull gray or brown with greenish or olive-brown tints. It has a whitish stripe along each side and two to four rather conspicuous angular, blackish spots in a row on each side of the hind part of the back. The head is light yellowish brown with a color network of darker brown.

The Pupa.

This is mahogany brown and about three-fourths of an inch long.

The Moth.

The moth (Plate One, fig. 11) expands about an inch and a half. Its back between the wing bases is reddish sooty gray, with a pale gray or whitish collar in front. The upper side of the abdomen is light brown. The under side of the body is dark gray, with light gray or even whitish sometimes prevailing on the sides and hind part of the chest. The fore wings are mostly dull brown above, usually tinged slightly with reddish or bluish. Each has a conspicuous triangular pale patch reaching back from near the middle of its front margin and nearly dividing an equally noticeable dark brown area, also some blackish markings toward the base and a blackish spot toward the outer end and running back from the front margin. The under side of the fore wings is light brown. The hind wings are whitish with brown shadings.

Treatment.

Flooding.

On bogs that cannot be reflooded.—Prevention: Do not let off the winter water between May 23 and June 15.

On bogs that can be reflooded.—If the net count (p. 3) shows treatment is necessary, flood about June 30 for 15 hours.

Spraying.

Spraying bogs while the worms are small never has been fairly tried. A spray of 6 pounds of dry lead arsenate in 100 gallons of water should be effective. The worms are hard to poison after they are half-grown.

Baiting.

See page 26.

Black Cutworm.[38]

This pest attacks cranberry bogs seriously only when the winter flood has been held till the last of May or later. It sometimes works with the spotted cutworm and also with the armyworm.

Distribution and Food Plants.

Important outbreaks of this pest have occurred in Indiana, Oregon and India[39], on lands which, having been overflowed, became drained at a time favorable to egg laying by the moths. It inhabits nearly the whole civilized world. Apple, asparagus, bean, beet, cabbage, chicory, cotton, corn, grape, grass, onion, potato, spinach, squash, strawberry, tobacco, and tomato are among its food plants. The worms devour each other and spotted cutworms greedily.

Character of Injury.

This worm works on cranberry vines much as the armyworm does (see p. 33).

Description and Seasonal History.

The life history has not been traced thoroughly. There seems to be much irregularity in it. The insect winters as a worm in various stages of growth and sometimes as a pupa. The moths are active from late May till late October. There probably are two broods in this state, the moths of the first being most abundant in June and July and those of the second in August and September. Egg laying occurs in June and July,—probably throughout most of those months. The eggs are said to hatch in about twenty-two days.

The Worm.

In its early life this caterpillar usually is mostly a rather indefinite greenish brown or gray in color, the green element being due to the food in the worm rather than to dermic pigment. When more mature (Plate Two, fig. 5), it is mostly dark brown or sooty gray on the back and sides and grayish below. A rather indefinite and inconspicuous broad stripe of somewhat lighter brown usually runs along the back. The head, the neck shield and the spiracles are mostly black.

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[38] *Agrotis ypsilon* (Rott.). Also known as the "greasy cutworm."

[39] Rockwood, L. P., 1925. Journ. Econ. Ent., Vol. 18, No. 5, p. 717.

These worms have a peculiar disgusting appearance that has been described as "greasy". They are about an inch and a half long when mature and often are very active in the afternoon.

The Moth.

The moth (Plate One, fig. 10) expands nearly one and three-fourths inches. The head is mostly reddish brown. The collar is sooty gray with a transverse line of black. The front part of the back is sooty gray. The breast is light gray. The hind part of the body is pale brownish above and light gray below. The fore wings are mostly sooty above with a few inconspicuous black markings, the outer third of each being light brown. They are pale brownish underneath. The hind wings are pale with brown shades toward the margins.

Treatment.

Flooding.

On bogs that cannot be reflooded.—Prevention: Let off the winter water before May 25.

On bogs that can be reflooded.—Flood for 15 hours as soon as the net count (page 3) shows it is necessary.

Spraying.

What has been said of the blossom worm in regard to spraying is true of this pest also.

Baiting.

See page 26.

Armyworm.[40]

This notorious cutworm infests bogs after late draining of the winter water oftener than the others. It may attack if this flood is let off at any time between about May 27 and about July 10. It never harms a bog drained early unless it is very grassy or is reflooded for ten days or longer in late May.

The moths seem to fly at times with the prevailing winds for many miles in great numbers and alight in a body to lay their eggs in a place favorable to the development of the worms. This accounts for the sudden appearance of this insect in regions remote from any known source of infestation. A few of the moths appear every year over most of the area in which it occurs, but this does not explain the sudden great invasions that come from time to time.

Armyworm outbreaks nearly always start in the Southern States. They are noted there by the Bureau of Entomology of the United States Department of Agriculture, which predicts their spread into the North. They are more common after cold, backward springs.

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[40] *Cirphis unipuncta* (Haw.).

The armyworm feeds mostly in low meadows and among rank-growing grasses. Its movement in armies is not normal, but follows an exhaustion of food which compels it to spread to other places.

Distribution and Food Plants.

This originally was an American insect, but it now inhabits most of the world.

It prefers grasses, both wild and cultivated, and the grains, such as barley, corn, millet, oats, rye and wheat. When pressed with hunger a little, it attacks alfalfa, apple, bean, beet, cabbage, cauliflower, clover, cranberry, cucumber, flax, lettuce, parsley, pea, pepper, strawberry, sweet potato, watermelon, and other plants.

Character of Injury.

The worms nip off the cranberry leaves more freely than blossom worms and spotted cutworms do, sometimes nearly defoliating the vines. They also commonly cut new uprights nearly off, so that they break over and hang by a thread. They feed mostly at night and on cloudy days, but also travel and feed a good deal in bright weather.

Description and Seasonal History.

The life history of the armyworm has not been traced thoroughly, for it varies widely in different parts of the country. It seems to have six broods in the South and two in New England. It appears to winter here as a partly grown caterpillar, but probably survives only our mildest winters. The worms mature in the spring and go an inch or more into the soil to pupate. The pupal stage lasts two weeks or longer, and the moths emerge from the ground and fly at night, laying eggs for the next brood. These hatch in a week to ten days. The worms mature in about a month, go into the ground, pupate and become moths as described for the first brood. The moths appear in August and early September and lay their eggs, and the caterpillars from these hibernate.

It will be seen that the worms feed in the fall and early spring in one brood and in the summer in another. The latter only is destructive.

The Egg.

The eggs are laid in rows or masses of ten to fifty, mostly in the leaf sheaths of grasses and grains or on stubble or straw, usually in moist or shaded spots. Each moth commonly lays five to six hundred.

The Worm.

The young worms loop like spanworms and spin down on silken threads but soon lose these habits. The maturing caterpillar (Plate Two, figs. 1a and

1b) is smooth and rather dark. A broad dark brown stripe runs the length of the back and usually is divided by a broken pale line running along its middle. At each side of the dark back stripe is a narrower reddish yellow one, then a dark one, and lastly another reddish yellow one. These colors vary somewhat. The stripes are separated by pale yellow lines. The under side of the body is pale greenish brown. The spiracles are black. Each proleg of the four anterior pairs has a noticeable deep brown stripe across the middle of its outer side. The head is yellowish brown with a color network of darker brown. The mature worm is about an inch and a half long.

The Pupa.

This is reddish or chestnut brown at first, becoming blackish before the moth emerges.

The Moth.

Swarms of the moths often appear about street lights shortly before an outbreak of the worms. Cranberry men sometimes may be warned by this and should know the moth at sight. It usually spreads about an inch and five-eighths and is plain light brown (Plate One, fig. 12). Each fore wing has a white speck near the center of the upper surface and a dark shade running back obliquely from the outer angle.

The moths live on the nectar of flowers and the honeydew of certain insects, and sometimes many may be caught with sweet baits at night. As they rarely lay eggs near where they have developed and often fly many miles before doing so, there seldom are two outbreaks a year in any one locality.

Treatment.

Flooding.

On bogs that cannot be reflooded.—Consult the Bureau of Entomology of the United States Department of Agriculture as to the probability of an armyworm invasion. If an outbreak is predicted, do not hold the winter water after May 25.

On bogs that can be reflooded.—Flood for 15 hours as soon as the net count (page 3) shows treatment is necessary.

Spraying.

What has been said of the blossom worm in regard to spraying applies to this worm also.

Baiting.

See page 26.

Fall Armyworm.[41]

This insect is not known to have harmed cranberry vines in Massachusetts. It worked havoc in New Jersey in 1916[42] on several bogs bared of their winter water in mid-July. It sometimes injures grasses and grains greatly on Cape Cod and is therefore likely on rare occasions to infest a few bogs there if they happen to present favorable conditions when it is prevalent. This species attacks later than the other cranberry cutworms and is the only one, except perhaps the black cutworm, likely ever to infest a Cape bog seriously when the winter flowage is let off after July 20. It will not attack a bog drained much before July, this probably explaining why it has appeared as a cranberry pest in New Jersey and not in Massachusetts, for the Cape growers rarely follow the common New Jersey practice of holding the winter water until July to kill out weeds and insects.

Distribution and Food Plants.

This pest occurs yearly in Central America, Mexico, the West Indies, and South America and its worst outbreaks may originate in those regions. It is evidently a native of tropical or subtropical America. Apparently it cannot survive the winter north of southern Georgia or central Texas. In the years of its great abundance in the South great numbers of the moths fly northward, sometimes for hundreds of miles, and lay their eggs. These hatch and the worms develop into moths which again fly northward before laying. In this way the insect in favorable summers spreads over most of the eastern two-thirds of the United States and even to Canada before fall frosts halt it. It sometimes does immense damage to crops throughout this range. Its favorite food plants are grasses such as quack or crab grass, Bermuda grass, blue grass, Johnson grass, etc. It seriously injures alfalfa, clover, corn, cotton, cowpea, kafir, millet, oats, rice, sorghum, sugar cane and wheat. It sometimes attacks beet, bean, buckwheat, cabbage, grape, pecan, pepper, peanut, potato, sweet potato, strawberry, spinach, tobacco, tomato, turnip, and other plants.

The worms devour each other and other cutworms eagerly. They work rather freely in the daytime, even in sunny weather.

There usually are five broods a year in the Gulf states, but only one appears in any one place in the North.

When Outbreaks may be Expected.

General invasions of this pest occur nearly always after cold, wet springs. In parts of the Mississippi Valley it is called the "overflow worm," for the farmers attribute its outbreaks to the overflowing of the great river. There is evidence to support this belief. Cold and dampness seem to destroy the insect enemies that ordinarily control the pest but do not harm the worm itself. This may explain the outbreaks that occur almost yearly in scattered places in the South after periods of heavy local rains.

Character of Injury.

The work of this insect is like that of the armyworm (page 33).

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[41] *Laphygma frugiperda* (S. & A.).

[42] Proc. Amer. Cranberry Growers' Assoc. 47, p. 11, 1917.

Description.

The Egg.

The moths lay their eggs mostly at night, in masses of from fifty to five hundred, preferably on grass blades, though they may place them on any plant suitable as food for the young worms. Low-lying fields of grass or small grains often are chosen for this, so the outbreaks usually begin in bottom land. Sometimes the eggs are laid on lawns. They are light gray and always are covered with grayish down from the moth's body. Each egg is much flattened at the base. This stage lasts a week or more in the Northern States.

The Worm.

The newly hatched caterpillar has a black head and whitish body. As they mature, the worms (Plate Two, figs. 8a and 8b) much resemble armyworms and vary greatly in color. The body is striped lengthwise on a ground color varying from buff to dull gray or nearly black. A pale yellow line divides lengthwise the broad mottled-buff stripe covering most of the back. On each side of this broad stripe is a light line, then a dark stripe, and lastly—nearly down to the legs—a light yellow stripe mottled with reddish. The under side is pale, varying from buff to green, and often tinged with red, especially toward the sides. Tubercles appear plainly as dark dots, particularly along the back. The head is deep brown mottled with pale yellow and always has an inverted white "Y" on the face. The worm matures in about three weeks in the North, becoming an inch and a quarter to an inch and a half long.

The Pupa.

The pupa is like that of the armyworm but a little smaller, being one-half to three-fourths of an inch long. It is light green at first but soon turns light brown and finally almost black. It is formed in a cell an inch or so in the ground.

The Moth.

The moth expands from an inch to one and three-eighths inches and has a pale-brown body. The fore wings of some specimens (Plate One, fig. 9) are mottled brown, with one whitish area near the tip and another running back obliquely from near the middle of the front margin; those of others are uniformly dark grayish-brown. The hind wings are whitish with a pearly or pinkish luster and edged with smoky brown.

The moths are attracted strongly to lights.

Treatment.

Flooding.

On bogs that cannot be reflooded.—The Bureau of Entomology of the United States Department of Agriculture notes the more severe outbreaks of this pest in the South and predicts their spread into the North. Growers planning to hold winter flowage till July should consult the Bureau as to the chance of an invasion before doing so.

On bogs that can be reflooded.—Flood for 15 hours as soon as the net count (see page 3) shows it is necessary.

Spraying.

What has been said of the spotted cutworm in regard to spraying is true of this insect. Spraying with lead arsenate is a standard control in the South.

Baiting.

See page 26.

SPANWORMS

These insects, known also as loopers and inchworms, have a striking way of crawling. They stretch out at full length, take hold with the front legs, and then bring forward the hind end close to the front pairs of feet, the body between bending well up out of the way. This habit is due to the lack of several legs that other caterpillars have to support the middle of the body. The hind part has only two pairs of legs.

These worms are more slender than most caterpillars. They are hairless and feed openly, never sewing leaves together. When disturbed they cling to their support by the hind pairs of legs and remain straight and motionless. As they usually are colored to harmonize with their habitual surroundings and often resemble short or broken twigs, this habit tends to save them from their enemies.

These insects commonly attack bogs here and there in Massachusetts but, save the chain-spotted geometer, have never been reported as doing so elsewhere. The kinds seen most on the bogs may be distinguished by the following:

Table of Worms.

Body mostly pale yellowish or pinkish, with a reddish herringbone stripe along the back .... *Eupithecia miserulata* Gr.[43]
Body mostly yellow .... chain-spotted geometer (p. 46).
Body mostly green .... green cranberry spanworm (p. 39).
Body mostly brown or gray 1

1. With a row of conspicuous irregular reddish yellow spots along each side .... red-spotted spanworm.[44]
Not thus marked 2

2. With a pair of noticeable tubercles a little way from the middle of the back 3
Without such tubercles .... brown cranberry spanworm (p. 41).

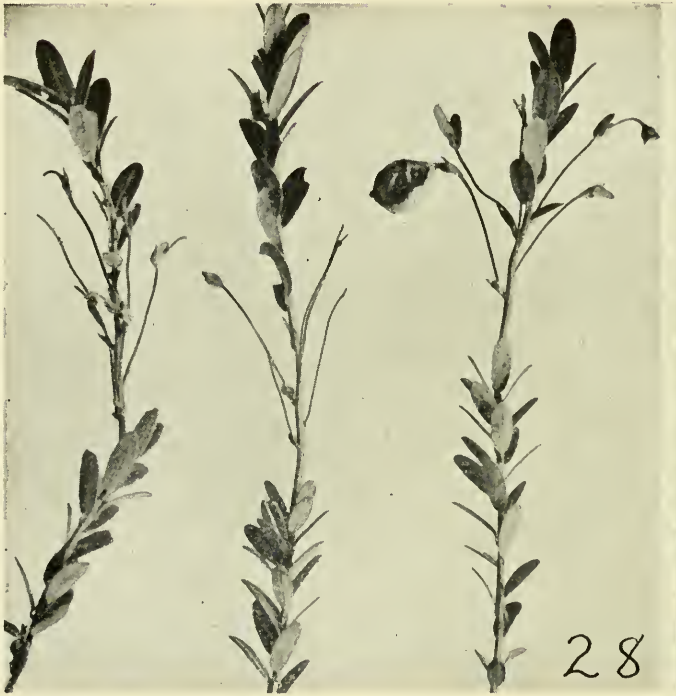
3. The tubercles in front of the middle of the back .... cotton spanworm (p. 44).
The tubercles behind the middle of the back .... big cranberry spanworm (p. 44).

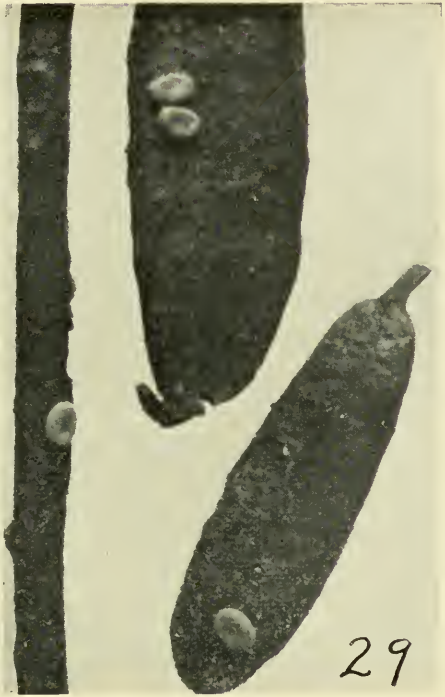
The green cranberry spanworm and the brown cranberry spanworm are far more important pests than the others, and when either of them becomes prevalent it usually stays with the bog year after year till it is treated. They

---

[43] An unimportant worm that often eats into the green berries and into meadow beauty flower buds.

[44] An unimportant worm, nearly an inch and a half long when mature, rather common during the first half of June on dry bogs and bogs that are not reflooded. It also attacks swamp blueberry. The moth has not yet been reared.





Green Cranberry Spanworm.

Fig. 28. Cranberry uprights from which worms had nipped flowers and berries.
Fig. 29. Eggs on litter from bog floor. Much enlarged.

seem never to harm dry bogs much. They attack mostly bogs flowed during the winter and not reflooded much in June. If they are once thoroughly eliminated from a bog, their presence in destructive abundance need not be feared again for several years. Extensive outbreaks of the two species probably have occurred nearly simultaneously and after marked general reductions of the black-headed fireworm, for the June reflooding and the lead arsenate spraying formerly generally practised to control the fireworm check these worms also. They are likely to be more prevalent than heretofore because the nicotine sulfate spray that has displaced lead arsenate as a fireworm treatment does not harm them much.

Growers should know the moths of these two species, for their abundance indicates coming trouble.

Green Cranberry Spanworm.[45]

This species occurs in limited numbers on most Cape Cod bogs every year and sometimes does extensive harm. It broke out on many bogs in 1920 and 1921, destroying the entire crop promise on a considerable acreage. Growers of long experience said it had been similarly prevalent for a time some twenty years before.

Distribution and Food Plants.

The moth has been found in Massachusetts, New York, New Jersey, Wisconsin and Vancouver Island. No food plant besides cranberry is known.

Character of Injury.

When the winter flowage is held till mid- or late May, some of the worms hatch in time to eat into terminal buds like false armyworms (fig. 22). They seldom do much harm in this way. They usually work like the blossom worm, nipping off flower buds and blossoms by severing the stem near where it joins the ovary (fig. 28). When extremely abundant they attack the leaves and sometimes brown a small area.

Description and Seasonal History.

The Egg.

There is one brood a year. In late June, July and early August the female moths scatter their eggs singly among the litter under the vines, laying about 125 each. They usually stick to fallen leaves or pieces of dead twigs (fig. 29). They are greenish white, elliptical, and about a thirty-seventh of an inch long. They are surprisingly rigid and unyielding as they come from the moth's body and, when examined with a microscope, are seen to be thickly studded, except more or less on a central area above and below, with minute shiny round smooth white tubercles (fig. 30). They often become somewhat sunken in the middle as hatching approaches. The winter flood does not harm them even when held rather late. When it is let off in April, hatching usually begins about May 15 and continues till about July 1.

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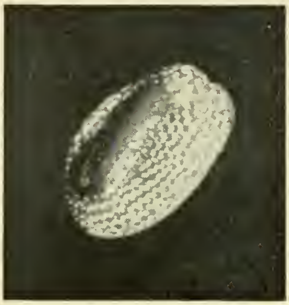
[45] *Itame sulphurea* (Pack.). Heretofore known in cranberry literature as *Cymatophora sulphurea*.

The Worm.

During most of their life the worms (Plate Three, figs. 3 and 4a) are green with several white lines along the back and sides and a narrow light yellow stripe along each side. In their last stage (Plate Three, fig. 4b) the green has a yellow tinge and the whitish lines are obscure except for a pair along each side of the back which often are more marked. They mature from about June 10 to about July 22, becoming an inch long.



Green Cranberry Spanworm.

Fig. 30. One egg. Greatly enlarged.

The Pupa.

The worms pupate in the litter under the vines. The pupa is pale greenish at first but becomes dark brown as the moth develops. It is about a third of an inch long. This stage lasts about ten days.

The Moth.

The moths emerge irregularly from late June till early August, the males tending to appear first. The male (Plate Three, fig. 2) is pale yellowish. Its head bears long pectinate feelers. Its wings expand a little over an inch.

The female (Plate Three, fig. 1) is sulfur yellow and expands about seven-eighths of an inch. Its wings have noticeable brown spots which vary, but commonly are arranged as follows: The upper surface of each front wing with three against the front margin, one against the hind margin, one in front of the center, and five to seven small ones along the outer border; the under side of the front wing with one in front of the center, some small ones along the outer border, and a streak toward the outer end and parallel with the outer border; the upper side of each hind wing with a spot in front of the center, another against the hind margin, and several toward and on the outer border; the under side of the hind wing with one near the center and often a series running parallel with the outer border. All the wings have brown sprinklings on the under side and the outer borders on fresh specimens have brown fringes. The moths brush off many of their scales, often losing their markings and even their yellow color. The feelers on the head are threadlike.

The males are more active than the females, but they rest much among the vines, flying less than the males of the brown spanworm. They are flushed up easily and sometimes rise in clouds from a badly infested area. The period of activity of the moths coincides with that of the brown spanworm caterpillars, and when both species abound on the same area they often are confused in the minds of growers.

Treatment.

Reflooding for 15 hours and spraying with 6 pounds of dry lead arsenate in 100 gallons of water are both very effective. Three treatments, about May 30, June 12 and June 25, may be necessary because of the long hatching period. The first, especially if flooding is done, often will check other pests also, especially the gypsy moth, the black-headed fireworm, the false armyworm and the blossom worm. If the infestation is only mildly serious, two treatments, about June 5 and June 25, will suffice.

Regular resanding tends to keep this pest out, for the sand covers many of the eggs so that the worms fail to emerge.

Brown Cranberry Spanworm.[46]

This insect attacks some bog severely almost every year. It broke out on so many in 1919 and 1920 that it was one of the most important cranberry pests. It does more harm than all the other bog spanworms together.

Distribution and Food Plants.

This insect has been found in Maine, Massachusetts, New York, Colorado, Alberta and Alaska. Its only known food plants are cranberry and bearberry[47].

Character of Injury.

Moderate infestations work much like the green spanworm, nipping off the blossoms and small berries, but they attack the leaves more and chew into and eat holes through the flower buds and often excavate the partly grown berries much as katydids do. A severe infestation sometimes turns a whole bog brown and then many of the worms probably die of starvation.

This worm works so late in the season that when its attack is severe it destroys all chances of a crop in the following year, and sometimes patches of vines fail to recover fully for a year or two.

Description and Seasonal History.

The Pupa.

The pupae winter among the litter under the vines, enduring the winter flood even when it is held till June. They are brown and somewhat over three-eighths of an inch long and have no cocoon.

The Moth.

If the winter flood is let off before May 1 and the season is warm a few moths often appear late in May, but they usually emerge mostly during the first half of June and are active till toward its end. Where the winter water is held till late May they emerge mostly in late June and fly into July. They are noticeably protandrous in emerging. The males fly freely, often swarming in clouds over badly infested areas; but the females, heavy with eggs, can only flop along the ground.

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[46] *Ematurgia amitaria* (Gn.). Heretofore known in cranberry literature as *Epelis truncataria* var. *faxonii*.

[47] *Arctostaphylos Uva-ursi* (L.) Spreng.

The female (Plate Three, fig. 5) is a finely sprinkled grayish or yellowish brown. The wings have vague and variable brown and whitish markings and the hind ones much yellow also on their upper surfaces, and are mostly yellow or yellow and white underneath with liberal general sprinklings of brown. They all on both their upper and lower surfaces usually have two or three poorly defined and often more or less broken brown markings running from the front to the hind margin. The back, especially between the bases of the wings, is mostly dingy brown and the scales on the under side of the body and on the legs are mainly pale yellow. The antennae are threadlike. The wings spread nearly an inch.

The male (Plate Three, fig. 6) spreads somewhat over an inch. The body and head above and the large bushy antennae are dingy brown with a sprinkling of pale yellow. Underneath, the body, head and legs are clothed mostly with light yellow hair and scales. The front wings are coffee brown above with two or three indefinite and irregular darker brown markings running from the front to the hind margin of each and often with touches of white. The hind wings are mostly deep yellow above with a strong general sprinkling and three rather vague cross markings of brown and with the outer border brownish. Beneath, the wings are deep yellow with a general sprinkling and usually two irregular cross markings of brown.

The Egg.

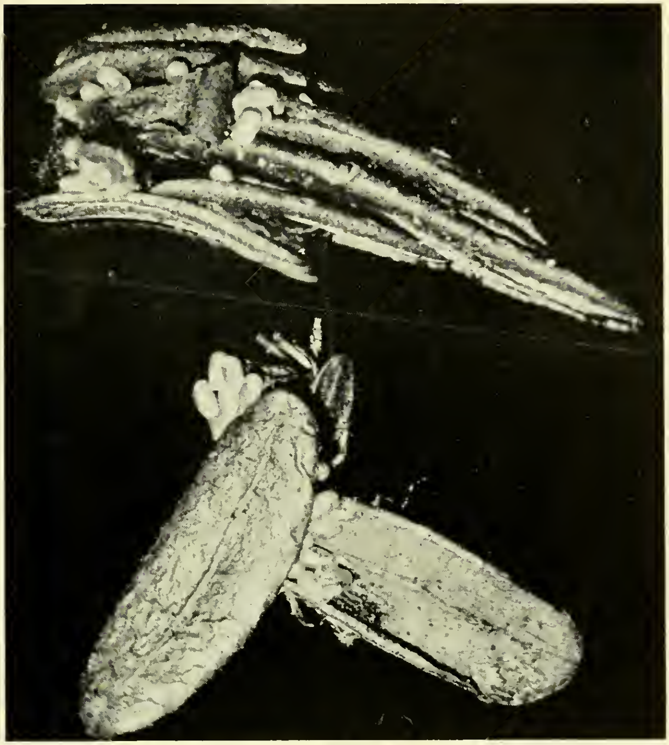
The female moths lay about three hundred eggs each. They thoroughly hide nearly all of them among the litter on the bog floor, mostly in irregular clusters of sometimes as many as twenty (fig. 31). The eggs are elliptical and about a twenty-seventh of an inch long. They are light green at first but turn yellow. If the winter flood has been let off early, they usually begin to hatch about July 1, but sometimes in advanced seasons by June 20.

The Worm.

In its early stages the worm is rather light brown with a whitish stripe along each side and another along the middle of the back. The latter tends to persist but becomes obscure as growth proceeds.

The mature worm (Plate Three, figs. 7a, 7b, 8a and 8b) is somewhat over an inch long and is grayish brown, varying greatly in shade, the under half being lighter than the back and the back often having various indefinite markings of darker brown. A whitish stripe often runs along each side just below the spiracles. The spiracles are orange-brown, rimmed with dark brown. The body has no noticeable tubercles and is covered with a fine whitish or sometimes partly brown scurf, seen only with a good lens. The head is indented only slightly and is chestnut brown commonly marked with darker brown across the top.

The worms mature in late July and early August and change into the pupae that pass the winter.



Brown Cranberry Spanworm.

**Fig. 31. Eggs among litter from bog floor.
Much enlarged.**

Treatment.

June reflooding interferes enough with the progress of the moths onto a bog and their egg laying there to prevent the development of an infestation where it is practiced regularly. Complete flooding for 36 hours as soon as the moths reach the height of their flight often very nearly eradicates a bad infestation, but this cannot be relied on.

It seldom is practicable to flood a bog when the worms are active. A spray of 6 pounds of dry lead arsenate in 100 gallons of water is very effective, especially if applied while the worms are hatching.

If the moths have been flying in great numbers, the vines should be examined with an insect net daily from about June 20 till the worms begin to hatch. Then spraying should begin at once and all the infested area be treated in two days, even if it takes several spraying outfits. These worms sometimes give a net count of over 2000 to 50 sweeps, and such an infestation can destroy a fine crop promise within a week after hatching begins.

Cotton Spanworm[48].

The late J. B. Smith gave us what we know of this species on cranberry bogs. He found it in 1883 infesting severely a bog in Cotuit[49]. There is little evidence that it attacked other bogs or has appeared as a cranberry feeder at any other time. Its attack probably was due to unusual abundance, for it broke out as a strawberry pest in Illinois the same year. As it may appear on bogs again, it is discussed here.

Distribution and Food Plants.

This spanworm ranges over most of this country east of the Rocky Mountains. It feeds on ash, apple, asparagus, blackberry, clover, cotton, cranberry, elm, geranium, guava, hickory, honey locust, maple, orange, pear, strawberry, willow and yellow dock. It attacks asparagus and cotton oftenest.

Character of Injury.

The first brood starts near the edge of a bog. The second starts from inside centers where groups of eggs have been laid. The worms were so abundant in the recorded infestation that they browned quite an area. They advanced in masses like armyworms.

Description and Seasonal History.

The worms first appear in June and mature late in that month or early in July. They are then about an inch and an eighth long and vary from yellowish to brown or livid gray, being streaked and mottled with lighter and darker shades. There are two low black tubercles on the back about a third of the length back from the head and two smaller ones near the hind end. The head is marked with irregular black cross bands.

The worms go into the ground a little and change into rough brown pupae about half an inch long from which the moths emerge in nearly two weeks.

The caterpillars of the second brood mature in August, beginning to pupate before the ninth but continuing to abound till after the middle of the month. The moths appear at the end of August and in September.

The moth (Plate Three, fig. 12) varies considerably in size, color and markings. Its wing expanse is from a little less than an inch to nearly an inch and a half. It is ash gray and the wings are crossed by irregular brown lines. The first abdominal segment is white above. The antennae of the female are threadlike, those of the male pectinate.

Treatment.

Spraying with 6 pounds of dry lead arsenate in 100 gallons of water is advocated.

Big Cranberry Spanworm.[50]

Some growers say this species is destructive on rare occasions. A few of the worms often occur on the bogs and sometimes defoliate small patches.

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[48] *Cleora pampinaria* (Gn.). This insect has been known heretofore as the cranberry spanworm.

[49] U. S. Dept. Agr., Div. Ent., Bul. 4 (O. S.), pp. 26–28, 1884.

[50] *Abbotana clemataria* (S. & A.).

Distribution and Food Plants.

The insect ranges from Canada to Florida and Missouri. It feeds on apple, clematis, cranberry, false dandelion, hickory, maple, pear, live oak, and white oak.

Description and Seasonal History.

This species winters as a pupa. The moths emerge late in May and soon lay their eggs. These hatch toward mid-June. The worms mature and pupate in July. There is but one brood a year.

The Egg.

The eggs are laid in clusters, often of as many as 432. They are green at first but turn reddish, then black—the last color only two or three days before hatching.

The Worm.

The caterpillars are almost black at first, but as they grow they become chocolate brown. The mature worm (Plate Three, fig. 9) is fully two and a half inches long. Most of its surface is very smooth. A noticeable dark ridge bearing a few low tubercles crosses the back opposite the second pair of legs. The back in front of this ridge and the head are lighter brown than most of the body. The under side between the legs at the hind end is lighter still. The spiracles are yellow, rimmed with black. On the back there are a pair of noticeable tubercles somewhat behind the middle and a moderate double tubercle toward the hind end. The top of the head is rounded and not much indented.

The Pupa.

The pupa (Plate Three, fig. 10) is somewhat over three-fourths of an inch long and a fourth of an inch thick. It is coffee brown and, with the exception of the wing cases, has an irregular sprinkling of dark brown. The spiracles and their surroundings appear as conspicuous black spots along the sides. The surface is dull and rough. This pupa never gets hard and firm as most pupae do, but always yields to the touch.

The Moth.

The moth (Plate Three, fig. 11) is light gray, dully variegated with rusty brown. The wings, the abdomen and the legs are sprinkled lightly with black scales. The thorax is whitish beneath and pale brown above. The head is light rusty brown, with the top between the bases of the feelers pure white.

The wings spread about two inches. Their outer edges are irregular and the tips of the front ones are sharp-pointed. A nearly straight line running from near the tip of each fore wing diagonally across its upper surface to the hind margin is whitish on the outer side and brown on the side toward the body. A similar line runs part way across the upper surface of each hind wing from beyond the middle of the hind margin. All the wings have a conspicuous dark brown speck somewhat back from the middle of the front margin on each surface.

Treatment.

Because of the size which these worms attain, their net count should rate as that of cutworms (see page 3). A spray of 6 pounds of dry lead arsenate in 100 gallons of water should be used when they hatch.

Chain-spotted Geometer.[51]

Neglected bogs with a dense growth of birches on the surrounding upland, usually areas that never are flooded, occasionally have this spanworm crawl onto them in such numbers that the vines are browned for some distance from the margin. The worms often are reduced greatly by parasites and a fungus disease[52]. A few of them appear on most dry bogs yearly.

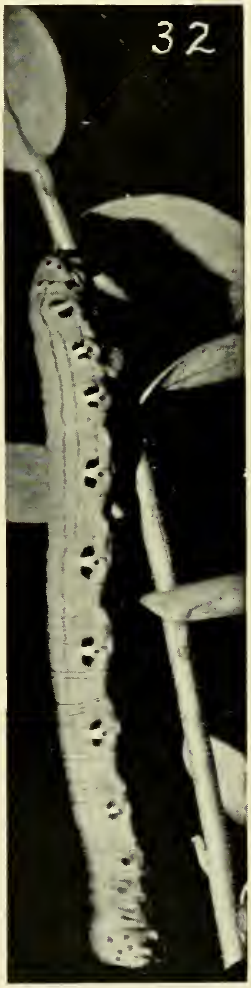
Distribution and Food Plants.

This species ranges through the Atlantic States and southeastern Canada and west to Colorado. Gray birch seems to be its favorite food plant, but it often defoliates alder, ash, low blueberry, dwarf blueberry, swamp blueberry, male berry, wild black cherry, bayberry, sweet fern, black huckleberry, wild indigo[53], red maple, white maple, sheep laurel, black scrub oak, meadow-sweet, poplar, red spruce, tamarack, white pine and willow. It also feeds on raspberry, blackberry, goldenrod, sweet gale, hazelnut, poison ivy, juniper, cranberry, rhodora[54], sedges, grasses, and probably numerous other plants.

Description and Seasonal History.

The Worm.

The worms appear in early summer and develop slowly maturing in late July and early August. They get to be nearly an inch and a half long. As they mature they have the habit of hanging straight and still, head downward (fig. 32), during the day. They seem to feed mostly in the evening or at night. They are yellow, with round black spots on the head, the neck shield the outer sides of the prolegs, and



Chain-spotted Geometer.

Fig. 32. Worm. Much enlarged.

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[51] *Cingilia catenaria* (Dru.).
[52] Caused by *Empusa Aulicae* Riechardt (det. Prof. W. H. Sawyer, Jr).
[53] *Baptisia tinctoria* (L.) R. Br.
[54] *Rhododendron canadense* (L.) BSP.

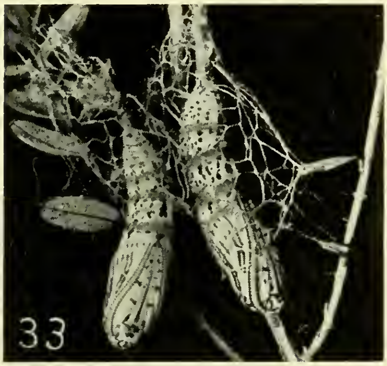
the very hind end. About thirty-two deep rusty-brown lines run along the body, some above, some below. There is a row of conspicuous white spots along each side, mostly above the spiracles, most of them bordered with one black spot in front and another behind.

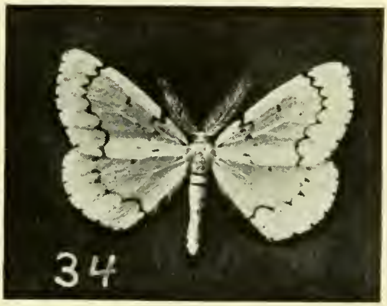
The Pupa.

The worms pupate in early and mid-August. The pupa is white, marked with black and yellow, and is about four-fifths of an inch long. It is formed in a slight but well-made net of yellowish threads among twigs or leaves or grass (fig. 33). This stage lasts about a month.

The Moth.

The moths fly in September and early October. They are so abundant sometimes that the males come to street lights in clouds. The females fly little if not disturbed. Both sexes have snow-white wings marked with zigzag lines and dots of black (fig. 34). The face is deep yellow and there is a patch of yellow in front of the base of each fore wing. The antennae of the male are very bushy, those of the female threadlike. The male expands about an inch and a half, the female an inch and three-eighths.





Chain-spotted Geometer.
Fig. 33. Pupae. Enlarged.
Fig. 34. Male moth.

The Egg.

One female sometimes lays as many as 368 eggs. They are scattered indiscriminately on the ground, mainly in the latter half of September. They hatch the following spring. They are greenish yellow at first but become brownish lavender in a few days. They are about a thirty-third of an inch long and are broadly elliptical with one end flattened or somewhat cupped.

Treatment.

Spraying with 6 pounds of dry lead arsenate to 100 gallons of water is advocated. If this is done on the upland when the worms are small it will prevent trouble on the bog later. Keeping the marginal ditch cleaned out and partly full of water, as advocated for the gypsy moth, secures a bog from infestation.

PLATE THREE

Spanworms and Harmless Insects sometimes Mistaken for Them.

GREEN CRANBERRY SPANWORM*:

Fig. 1.—Female moth.
Fig. 2.—Male moth.
Fig. 3.—Worm, side view.
Fig. 4a.—Half-grown worm, back view.
Fig. 4b.—Mature worm, back view.

BROWN CRANBERRY SPANWORM:

Fig. 5.—Female moth.
Fig. 6.—Male moth.
Figs. 7a, 7b, 8a and 8b.—Mature worms, side and back views, showing variation in coloration.

Big cranberry spanworm:

Fig. 9.—Worm.
Fig. 10.—Pupa.
Fig. 11.—Moth.

Fig. 12.—Cotton spanworm moth.

Fig. 13a.—The bog butterfly, Heodes epixanthe (B. & L.).
This often appears on bogs in great numbers in July and early August and is mistaken commonly by growers for a spanworm moth. It is practically harmless.

Fig. 13b.—The same, side view, at rest with wings erect.
No real cranberry pest ever rests with its wings held up so. Other kinds of butterflies, all with this habit, are common at times on many bogs.

Fig. 14.—Nomophila noctuella (D. & S.).
A harmless moth common on many bogs, especially from May to mid-July. It often excites suspicion.

PLATE FOUR

Gypsy Moth and Other Pests.

Fig. 1.—CRANBERRY GIRDLER moth.

Fig. 2.—Crambus proaefectellus (Zinck.).
An unimportant moth common on many bogs in June and early July and often confused by growers with the cranberry girdler. Note the single conspicuous white stripe along the middle of each fore wing.

Figs. 3a and 3b.—Cranberry spittle insect female adults, showing variation in coloration.
Fig. 4.—Cranberry spittle insect male adult.
Fig. 5.—Cranberry rootworm beetle.
Fig. 6.—Fire beetle beetle.
Fig. 7.—CRANBERRY ROOT GRUB male beetle.

GYPSY MOTH:

Fig. 8.—Caterpillar.
Fig. 9.—Pupa.
Fig. 10.—Male moth
Fig. 11.—Female moth.
Fig. 12.—Egg mass.

Figs. 13 and 14.—Calosoma sycophanta beetle and larva, predaceous on gypsy moth caterpillars and pupae.

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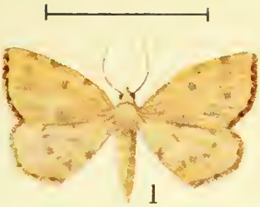
* The names of the more commonly harmful pests are in capitals.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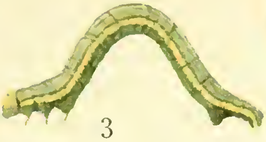
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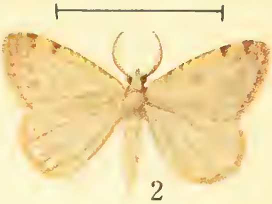
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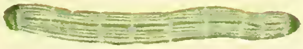
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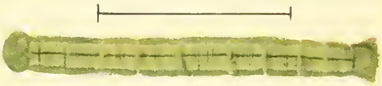
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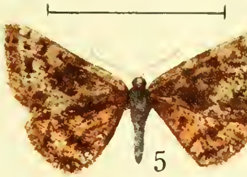
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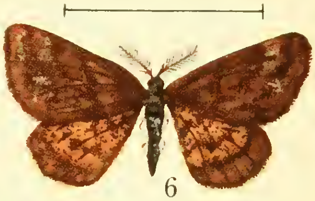
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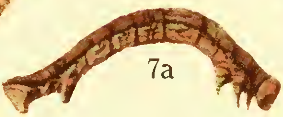
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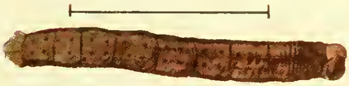
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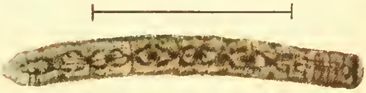
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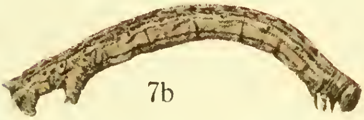
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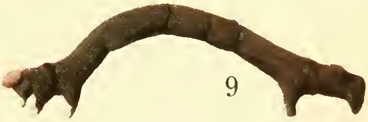
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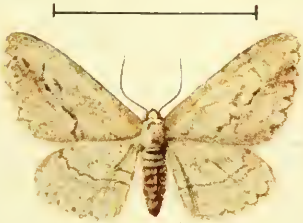
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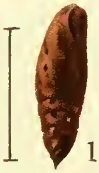
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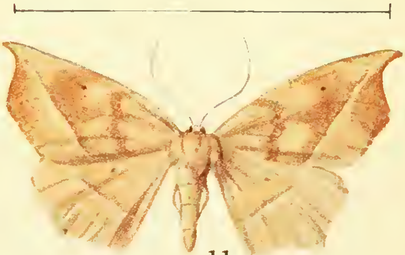
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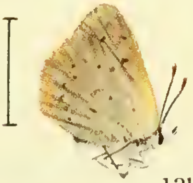
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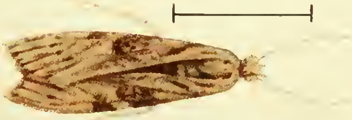
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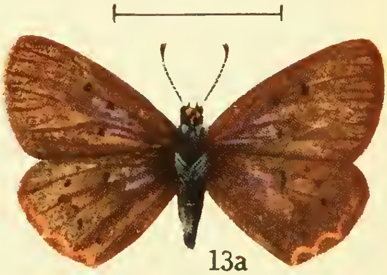
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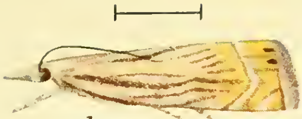
PLATE FOUR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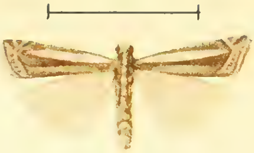
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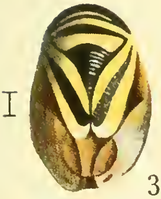
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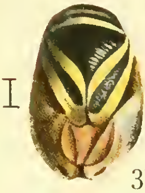
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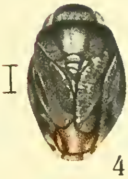
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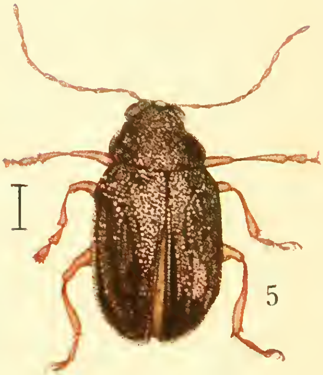
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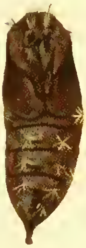
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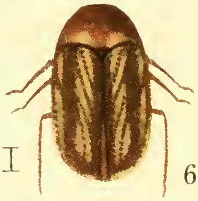
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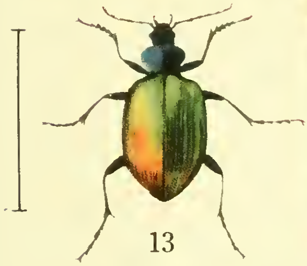
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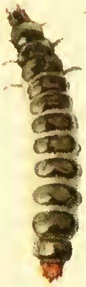
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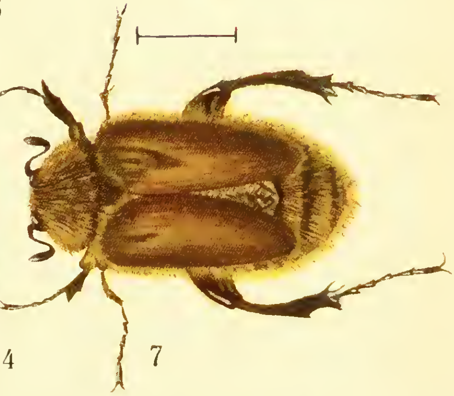
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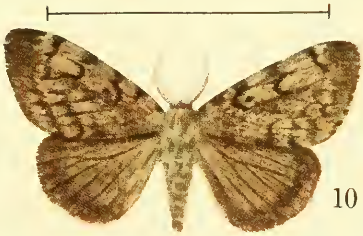
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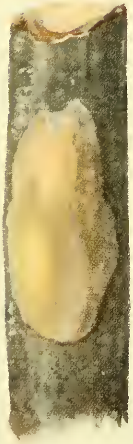
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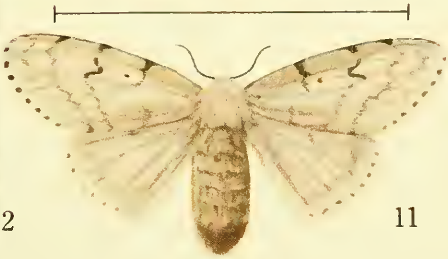
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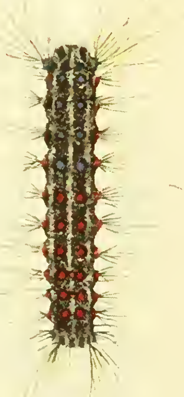
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Color Plates by Donovan & Sullivan Engraving Co., Boston, Mass.

Helen Morse, del.

HAIRY WORMS.

These caterpillars have copious hair over much of the body. They are open feeders, never sewing the leaves together. They are like cutworms in the number and arrangement of their legs and in their gait. Several kinds of hairy worms occur in small numbers on the bogs, but only three need notice here. They may be distinguished by the following:

Table of Worms.

	Head red	white-marked tussock moth.[55]
	Head not red	1
1.	Working in late spring and early summer	gypsy moth (p. 49).
	Working in late summer	*Datana* sp.[56]

Gypsy Moth.[57]

This Old World species brought into Massachusetts in 1868 did not infest the Cape cranberry region seriously till 1913. During 1913 and 1914 it increased vastly there, becoming an important cranberry pest. It did much harm on the bogs till 1920 when it decreased and was treated much more effectively by the growers. Its important natural enemies brought from abroad should check it largely hereafter, but it must be regarded as a permanent bog pest for it will have years of abundance.

Distribution and Food Plants.

This pest ranges widely through Eurasia and North Africa. In our country it still is confined to New England and areas in Ohio, New York and New Jersey. It has hundreds of food plants.

Character of Injury.

The young worms commonly attack the terminal buds first, eating all but the outer scales (fig. 35) and often causing great loss before the grower knows his bog is infested. As the new growth develops, the caterpillars greedily devour the leaves, flower buds and blossoms (fig. 36) and often sever the new part of the stem (fig. 37). They attack the old foliage severely when they are very abundant and have destroyed the more attractive new growth and sometimes even gnaw bark from the vines.

The work of this insect on cranberry vines is much like that of the false armyworm in all stages. This is true of no other pest.

An infestation of two first-stage worms to the square foot often develops so as to destroy nearly all the new growth, and one larva to the square foot usually reduces the crop materially.

Bogs usually do not yield well till the second year after severe injury by this pest, but vigorous vines often do so the next year.

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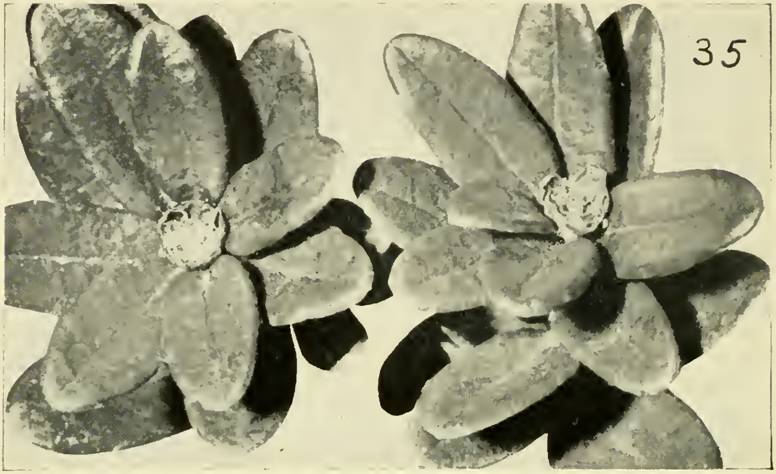
[55] *Hemerocampa leucostigma* (S. & A.). A beautiful caterpillar sometimes rather abundant on dry bogs but never very harmful.

[56] These worms sometimes defoliate small patches of vines in late August but never do much harm.

[57] *Porthetria dispar* (L.). See U. S. Dept. Agr. Bul. 1093, 1922.



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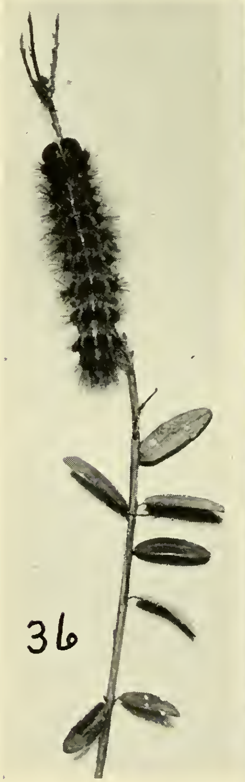

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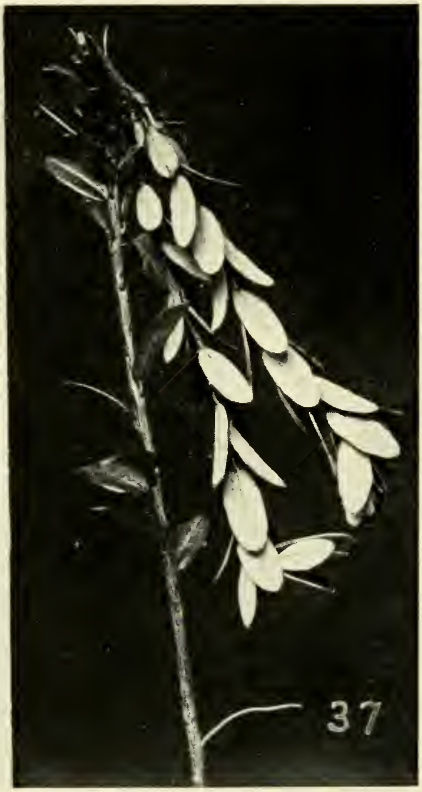

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Gypsy Moth.

Fig. 35. Cranberry tips with terminal buds eaten out by young worms. Much enlarged.

Fig. 36. Caterpillar and its work.

Fig. 37. Work of worms.

Description and Seasonal History.

The Egg.

The eggs are smooth, globular, about a twentieth of an inch in diameter and pale pinkish brown when first laid. They grow darker within three weeks when fertile, owing to the development of the worms. They are laid soon after the moths emerge, mostly in oval or rounded masses of four hundred to sometimes over a thousand (Plate Four, fig. 12). These are half an inch to an inch and a half long and a third of an inch to an inch wide. They are covered with yellowish hairs from the abdomens of the moths and look like pieces of sponge. They are laid in every conceivable place, but the trunks and branches of trees probably are the most natural locations. They usually are placed within a few inches of the pupal case from which the moth emerged.

The young worms become fully formed within three weeks after the eggs are laid. They cannot endure a temperature lower than—25°F. and often are winterkilled extensively in northern New England. Some hatch in September in rare instances, but they normally appear from the last of April to mid-June, according to the weather and their position, those in warm sunny places coming out earliest while those in cool shady locations emerge much later, most of them usually hatching between the 12th and the 25th of May.

The winter flowage of bogs does not harm the eggs much as long as it is cold, for they hatch readily afterward if it is let off early in April. If it is held till after May 20, the hatching is negligible.

The Worm.

The caterpillars in their first stage are very dark and, being clothed with long hair and provided with aerostatic hairs, are borne easily by the wind. It sometimes carries them twenty miles or more.

The worms grow rapidly during late May and June and mature in July. After their first stages are past they are as follows (Plate Four, fig. 8): The head is mostly sooty black, this color being much broken up by irregular light yellow markings, and has a long triangular stripe down the middle of the face and two converging curved lines on the top that are cream-colored and conspicuous. Its surface bears many yellow hairs. The under side of the body is mostly yellowish. The back and sides are rather dark brownish gray, with a light line along the middle of the back. There are eleven prominent tubercles in a row along each side of the back, the first five being blue and the last six red. These bear slender black spines and a few short pale yellow hairs. Tubercles on the sides have more and longer hair most of which is pale yellowish. Two small bright red tubercles without hair or spines, some distance apart on the mid-line of the back toward the hind end, and a conspicuous dark hairy tubercle on each side just behind the head are distinctive. The female worms often get to be two inches long, but the males seldom much exceed an inch.

The caterpillars spin much silk in their first stages and commonly drop and hang by a thread when disturbed. They do not do this when they get larger, but they spin a few threads for support before pupating and often make a scant cocoon.

The worms remain sheltered at night and feed in the daytime in their first stages, usually being most active from 9 to 11 A. M. and from 3 to 5 P. M. Their habits change as they grow and they feed mostly at night, remaining inactive and more or less concealed during the day unless they are starved.

The Pupa.

Pupation usually becomes general toward mid-July on the Cape, but some caterpillars remain till August. When the worms abound they commonly collect in masses to pupate. The male pupae are from three-fifths to four-fifths of an inch long and the female from three-fifths of an inch to one and two-fifths inches. They are deep brown and bear considerable yellow hair (Plate Four, fig. 9). They usually are found on the sand on cranberry bogs, often covered with litter, but they also occur up among the vines. The pupal stage lasts 7 to 17 days.

The Moth.

The sexes are very unlike. The male (Plate Four, fig. 10) expands about an inch and a half. Its antennae are bushy and with the upper side of the body and wings are dingy brown, the fore wings having irregular dark brown markings. The head and under side of the body are yellowish white. All the wings are light brown underneath.

The female (Plate Four, fig. 11) expands about two inches. Its antennae are dark brown and much less bushy than the male's. The hind end of the abdomen is dingy reddish brown. The rest of the body and the wings are nearly white. The fore wings are marked irregularly with different shades of brown and all the wings have dark brown spots at regular intervals along their outer margins.

The moths emerge in late July and August. The males are slender-bodied and fly actively by day with a peculiar zigzag flight, but the females are heavy-bodied and sluggish and cannot fly.

How Bogs Become Infested.

Bogs get infested in the four following ways:

1. *By the Hatching of Eggs laid on the Bog the Year Before.*—This is a common cause of trouble on bogs that have been neglected, especially dry bogs. These infestations usually defoliate rounded areas.

2. *By Wind Drift of the Worms in their First Stage.*—This is the main cause of infestation. The uplands around cranberry bogs, often from ten to fifty feet high and usually wooded, furnish ideal conditions for wind dispersion. Infestations from wind drift often are thickest near the bog margin and diminish toward the center. They seldom, if ever, develop in round patches.

Often there is a high mortality among the wind-borne larvae after they reach a cranberry bog. It seems to be greatest in their first stage and probably is due mainly to reduced vitality, this making them readily subject to disease and other killing agents. The nature of cranberry foliage as a food may be a factor.

3. *By the Worms falling on the Bog Margin from Overhanging Trees.*—The uplands around most bogs now are cleared of trees and brush well back from the margin, so the chances of this generally are small.

4. *By the Caterpillars crawling across the Marginal Ditch in their later Stages.*—When the surrounding upland is heavily infested, complete defoliation of the trees commonly occurs, and then the hungry worms often crawl onto the bog.

Treatment.

This pest is controlled readily on cranberry bogs by:

1. *Holding the winter flood till May 25.*—This kills the eggs laid on the bog the year before and usually catches most of the wind drift. See page 11.

2. *Reflooding about May 29 for 36 hours.*—The wind drift is generally about over then, and the water kills the worms before they do much harm unless they are very numerous. A fourteen-hour flood kills them after they are a third grown, but if they are abundant treatment should not be delayed after the above date most years. The date for the earliest springs is May 24 and for the latest June 3. Many of the small worms cling to the vines as the water rises and never come to the surface. As they grow they lose this habit. This may explain their greater resistance to drowning in their first stages. The larger worms thrash themselves to death on the surface of the water.

Late May is also the time to flood to control rose-bloom. If the water is held 36 hours the swollen pink shoots (Plate Two, fig. 6) caused by the disease collapse and dry up a day or two later.

This flooding also destroys other pests that may be at work, such as false armyworms, blossom worms, black-headed fireworms and green spanworms.

3. *Spraying with 6 pounds of dry lead arsenate in 100 gallons of water about May 22.*—The date should be about May 16 in very early springs and about May 28 in very late ones. This is very effective when the worms are small. They are hard to kill with arsenicals after they get large.

4. *Dusting heavily with one part of sodium fluosilicate mixed with four parts, by volume, of hydrated lime.* This is the only insecticide so far tried which kills the mature worms without reducing the crop much.

5. *Keeping the maturing worms from crawling onto the bog.*—This is best done by:

(a) Removing the trees, especially the oaks, and the brush for 150 feet from the bog margin. This also helps to prevent frosts somewhat by allowing freer air movements across the bog at night.

(b) Spraying the brush and trees for 200 feet from the bog margin with lead arsenate when the worms are small. This always is advisable if the upland has not been cleared and is thickly infested.

(c) Keeping the marginal ditch cleaned out and partly full of water, with a film of kerosene or fuel oil on the water, during the worm-crawl. Sometimes the ditch must be deepened considerably for this.

(d) Spraying the upland bordering the bog with fuel oil. This should be done only when the worm-crawl is thick and other measures have been neglected or are impracticable. It may have to be repeated several times unless the strip sprayed is wide. Short lengths of old hose should be used for this, for oil soon ruins hose.

MISCELLANEOUS PESTS.

These forms are placed here because their characters or habits are such that they cannot be grouped with others. The following table distinguishes them:

Table of Worms.

With legs .... cranberry fruit worm (p. 54).

Legless 1

1. With a head; working in the blossom buds .... cranberry weevil (p. 58).
Headless; working in the tips of the uprights .... cranberry tipworm (p. 63).

Cranberry Fruit Worm.[58]

This worm has been more destructve on the Cape than any other cranberry pest, sometimes taking nearly half the crop; but nature controls it some years so that it does no great general harm. It often takes all the fruit on a bog without proper winter flowage. It attacks early varieties more than late ones. It is also very injurious in Wisconsin, but not elsewhere.

Many moths probably come onto the bogs from a standing upland infestation most years in Massachusetts and Wisconsin, for new bogs made in isolated locations nearly always become infested in a few years. Infestations on bogs flooded during the winter might die out soon but for this continual invasion.

In Massachusetts, except in well-sheltered locations, the worms sometimes are winterkilled in their cocoons by wholesale when not covered with snow or water. If this occurs in New Jersey and on Long Island, where there is less snow, it may cause the scarcity of the pest there. The worms freeze in midwinter when exposed in their unbroken cocoons to air with a temperature of —2° to —3°F.

Distribution and Food Plants.

This species has been found in Maine (at Machias), Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Wisconsin, Texas and Washington.

The worms infest in the wild the fruits of the mountain cranberry[59] and swamp blueberry. They commonly web together several berries of these plants and feed among them. They probably have still other food plants for they eat dangleberries, black huckleberries, apples[60] and beach plums[61] freely in confinement.

Character of Injury.

The newly hatched larva almost always crawls over the surface of the cranberry from its place of emergence at the blossom end and enters close to the stem. Its entrance is so small that it is barely visible to the unaided eye. It eats the seeds and usually some of the pulp and then leaves the berry to enter a second. One worm destroys from three to six berries, the number varying with their size. Most of the pulp is eaten in all except the first (fig. 38). The entrance to the first two or three is closed by a white silken curtain (fig. 39). After the first berry, the worm is indifferent about the location of its entrance. It often goes from one berry directly into another at their point of contact (fig. 40). The berries turn red prematurely soon after they are attacked, this being the first sign of the work of this insect. They then gradually dry and shrivel and may cling to the vine as husks till the next year (fig. 41).

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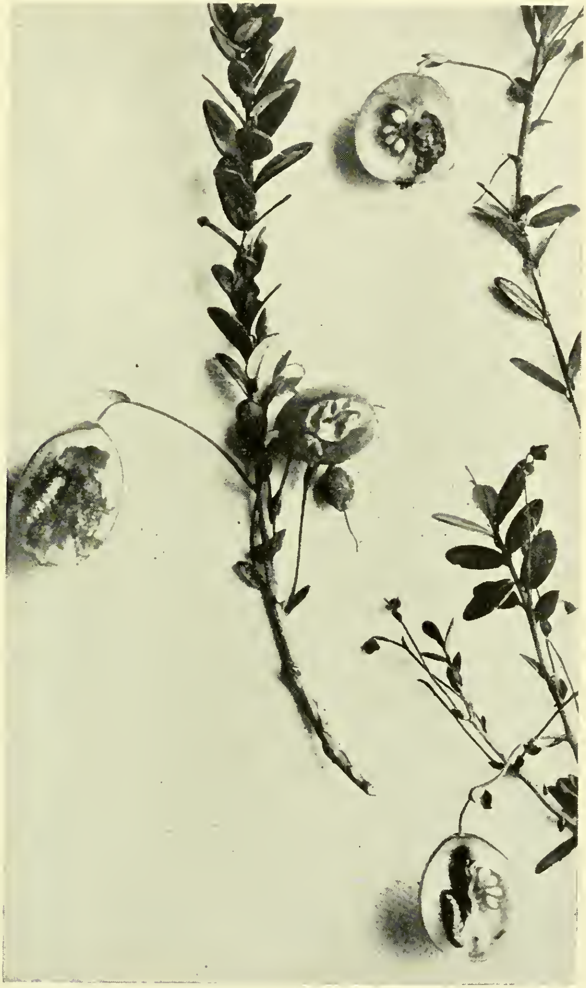
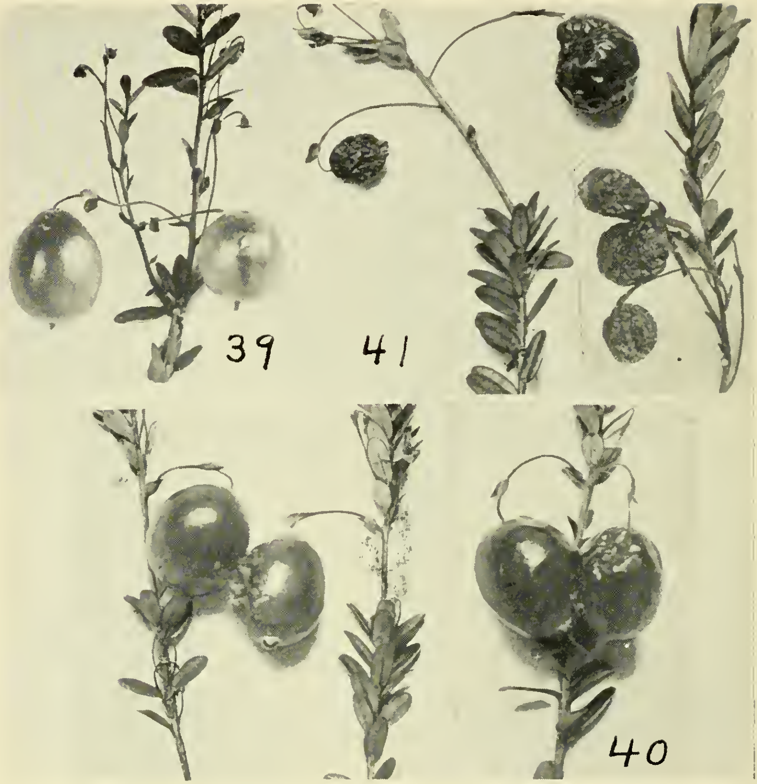
[58] *Mineola vaccinii* (Riley).
[59] *Vaccinium Vitis-Idaea* L. var. *minus* Lodd.
[60] *Pyrus Malus* L.
[61] *Prunus maritima* Wang.



Cranberry Fruit Worm.

Fig. 38. Cranberries cut open, with worms at work.

When the worms mature late many are gathered with the berries and sometimes do much harm among the stored fruit and in shipments, working some



Cranberry Fruit Worm.

Fig. 39. Cranberries with worm holes, one closed with white silken curtain.
Fig. 40. How the worms often work from one cranberry directly into another.
Fig. 41. Cranberries shriveled to dry husks because of its work.

years till late October. Here they web the berries into balls in which they feed.

Description and Seasonal History.

The Egg.

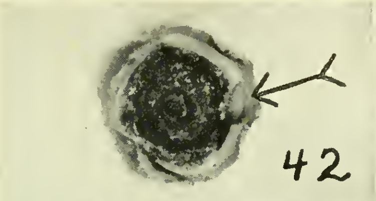
The egg is generally oval and so plastic when laid that it adapts itself readily to an irregular surface. It appears rather watery at first but soon becomes pale yellow and often develops an irregular reddish streak. It usually is placed under one of the lobes at the blossom end of the berry (fig. 42) but may be anywhere on the surface. More than one or two seldom are found on a berry unless the infestation is very severe.

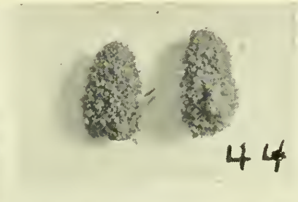
Egg laying begins when the small berries start to grow and sometimes continues till the last of August. The normal eggs hatch in about five days and parasitized ones in about eight days.

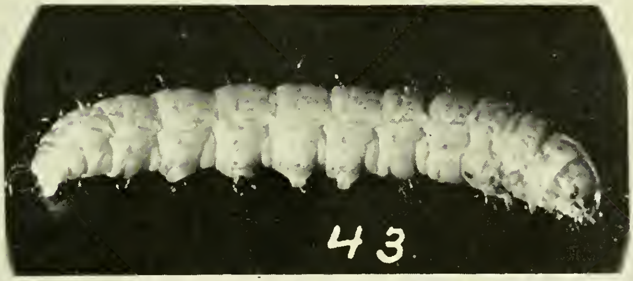
The Worm.

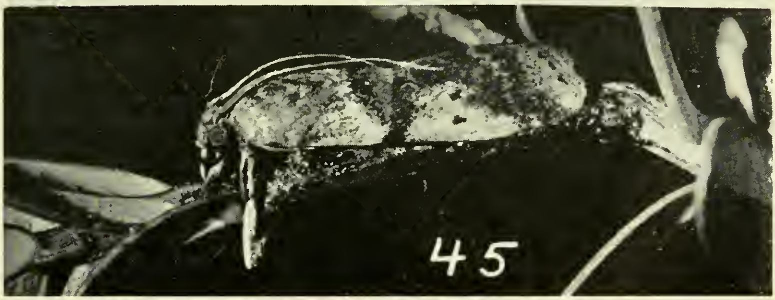
The normal mature worm (fig. 43) is about half an inch long and is green, often tinged with reddish on the back. The head is yellowish. The parasitized worms seldom become much over a third of an inch long.

The caterpillars are generally most active from about July 15 to about August 30, but usually some work in the berries well into September. When through feeding, they go down to the sand under the vines, on or near the surface of which they make oval cocoons (fig. 44) of sand and silk or of fallen cranberry leaves webbed together. Those of the normal worms generally are a little over three-eighths of an inch long, but those of parasitized ones are smaller and frailer. They are not impervious to water, for when submerged they nearly fill up in about five days. The worms in them generally are not much affected by cold water and many live through the winter under bog flowage.









Cranberry Fruit Worm.

Fig. 42. Egg under calyx lobe of cranberry. Much enlarged.
Fig. 43. Worm. Much enlarged.
Fig. 44. Cocoons. Somewhat enlarged.
Fig. 45. Moth. Much enlarged.

The Pupa.

Pupation occurs within the cocoons in late May and June on dry bogs and bogs drained of their winter water before mid-April. The pupa is pale greenish at first but soon turns yellowish brown and becomes dark brown before the moth emerges.

The Moth.

The moths occur from very late May till after mid-August, but abound most in July. They hide among the vines during the day and are hard to flush, so they seldom are seen by growers even when abundant. They are very active in calm evenings and may be seen at dusk hovering over the vines and alighting occasionally to lay eggs. They have been known to fly 272 feet in one flight and may travel surprisingly far during their life and come to bogs from considerable distances.

The moth (fig. 45) expands about two-thirds of an inch. The fore wings are mostly dark grayish brown above with a slight pinkish tinge, each having two whitish areas, one toward the base and one running back from beyond the middle of the front margin, there being two dark dots in the latter. The under side of the fore wings and both sides of the hind ones are light brown.

Treatment.

Spraying with arsenicals to check this insect has been tried thoroughly, but with little success. No practicable way to treat it on strictly dry bogs has been found.

Experiments have shown that the worms in their cocoons generally cannot endure submergence in water with a temperature above 60°F. over two weeks. Bog experience confirms this, for if the winter flood is held till after May 20 (see page 11) fruit worm trouble usually is much less than on bogs from which the flowage has been let off early. Bogs vary greatly in their tendency to become severely infested, often due probably to differences in their surroundings. Holding the winter flowage late every other year is a good control with some, but others need treatment nearly every year. Flooding for 18 days in the fall before the water cools too much is effective and should be practiced when the berries can be gathered early enough. The water should go on by September 25 if possible and before October 1 anyhow. This treatment also controls the blossom worm and the girdler. If it is to be practiced regularly and satisfactorily the winter flood should not be held late.

Cranberry Weevil.[62]

This insect works on dry bogs and bogs that are flowed for the winter but are not reflooded much. It is a minor pest, doing serious harm only on small areas here and there, but when it establishes a considerable infestation it usually stays for years unless it is treated.

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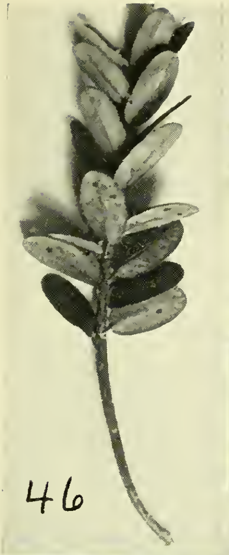
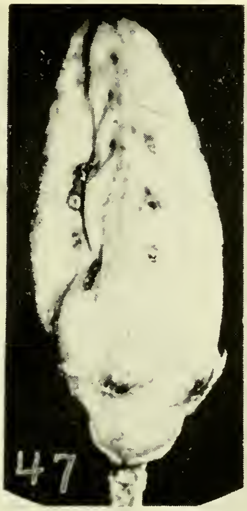
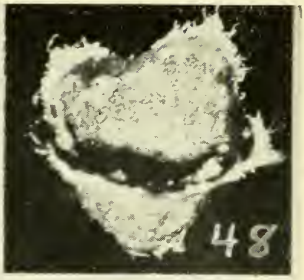
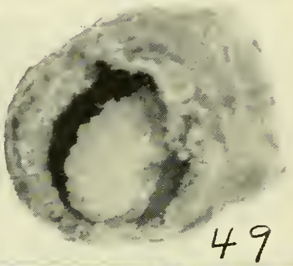
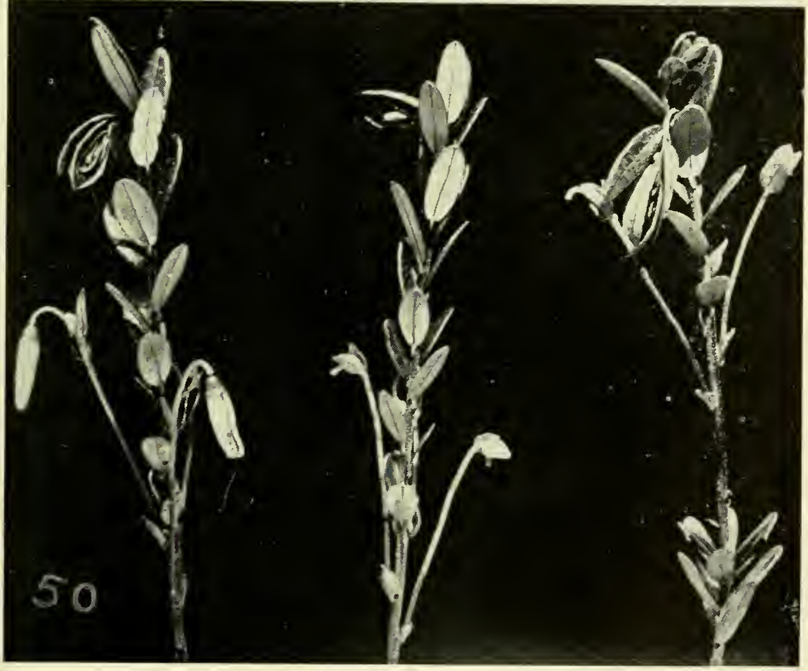
[62] *Anthonomus musculus* Say.—determined by W. S. Blatchley and H. C. Fall. The name *A. suturalis* Le C. has been tied to this species erroneously in cranberry literature.











Cranberry Weevil.

Fig. 46. Cranberry upright with holes drilled in leaves by beetles.

Fig. 47. Cranberry blossom bud drilled by beetles. Much enlarged.

Fig. 48. Ovary of cranberry blossom bud excavated by grub. Much enlarged.

Fig. 49. Cranberry blossom bud with ovary removed showing grub in unopened corolla. Much enlarged.

Fig. 50. Cranberry uprights with tips broken down and buds dropped, work of beetles.

Distribution and Food Plants.

This species ranges from New England to the Rocky Mountains and Florida. The beetle is found commonly on black huckleberry and the flowers of black chokeberry[63]. It feeds[64] on the flowers and leaves of swamp blueberry as well as on cranberry.

Character of Injury.

In the spring the beetles occasionally drill holes in the under side of the old leaves (fig. 46) and in the dormant buds. They turn their attention to the new growth as it develops, drilling into the new leaves and the growing blossom buds freely (fig. 47) and often eating the stamens. New shoots often are killed by this feeding, turning dark as if frosted or breaking over where the stem has been punctured.

The grub devours the pistil and stamens of the flower bud, leaving the excavated ovary (fig. 48) together with the unopened corolla (fig. 49) a mere shell[65]. If this is opened it usually is found to contain either the grub or pupa and some fine brown castings.

Many of the infested buds fall to the ground (fig. 50), some before the egg hatches. The cause is not known, but probably the beetle partly severs the pedicel somehow when it lays the egg. A few of the buds fall because the grubs eat them off from within. Buds that show they are partly cut off by shaking freely when the vines are disturbed indicate surely the presence of this pest.

The beetles of the new brood appear while the berries are small and feed voraciously on them (figs. 51, 52 and 53) and on the more tender foliage for about three weeks, riddling both with holes. Some of their work on the backs of the leaves at this time is very characteristic (fig. 54). This feeding decreases as the season advances and finally they only nibble the leaves occasionally, doing this till into September.

Where abundant, this insect often destroys the entire prospective crop by its work in the blossom buds, and the newly emerged beetles sometimes ruin most of the small berries and by killing the tips of the uprights make a crop the next year impossible.

Description and Seasonal History.

The Beetle.

The beetle (fig. 55) is about a sixteenth of an inch long. It has a slightly curved snout about a third as long as the rest of the body. This bears a geniculate feeler on each side beyond the middle and small jaws at the end. The wing covers are ornamented lengthwise with rows of little pits. Narrow white scales noticeable only under a microscope are scattered over the body and legs and often form transverse patches on the wing covers. When the beetle emerges from the pupa it is light brown, with the head and snout deep reddish brown and the eyes black. It changes to its normal color within two

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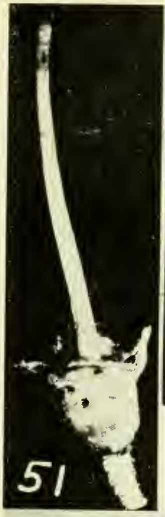
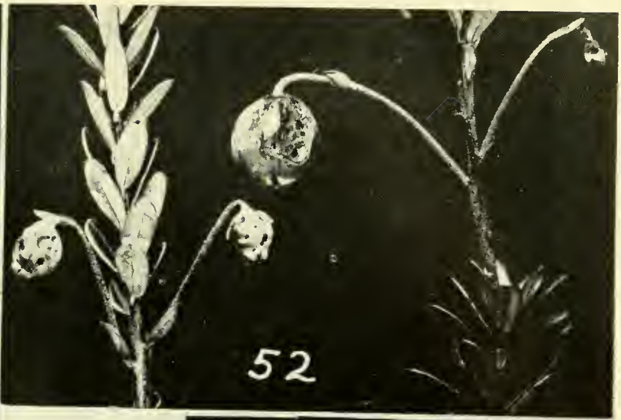
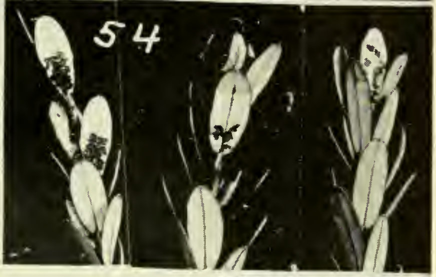
[63] *Pyrus melanocarpa* (Michx.) Willd.

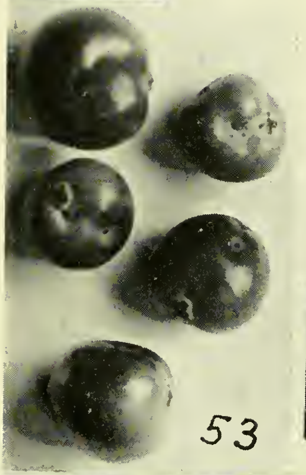
[64] According to H. B. Scammell.

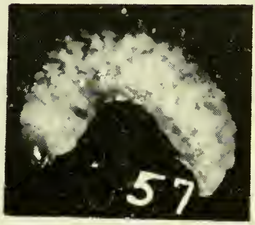
[65] The lobes of the corolla of an infested bud always remain closed tightly together and become dry and rigid in that position, a protective cell thus being formed for the insect.

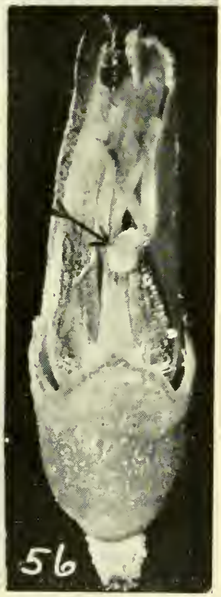


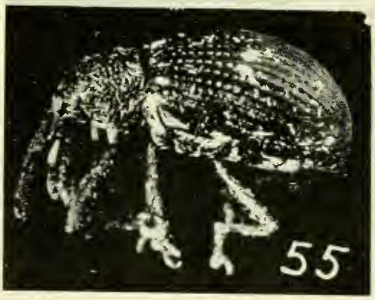


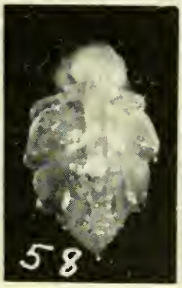












Cranberry Weevil.

Fig. 51. Newly set cranberry drilled by beetles. Much enlarged.
Fig. 52. Growing cranberries drilled by beetles.
Fig. 53. Cranberries with deformities due to drilling of beetles.
Fig. 54. Cranberry uprights showing characteristic work done by beetles on backs of leaves in July and August.
Fig. 55. Beetle. Much enlarged.
Fig. 56. Cranberry blossom bud with part of corolla cut away showing egg among stamens. Much enlarged.
Fig. 57. Grub. Much enlarged.
Fig. 58. Pupa. Much enlarged.

or three weeks, then being blackish with the wing covers, the legs and the under side of the abdomen mostly deep reddish.

There is one brood a year. The insect passes the late summer, fall, winter and spring as a beetle and can live under the winter flood. In the fall and spring the beetles hide in the trash under the vines or burrow a little in the sand on cold windy days, coming out only in warm sunny weather. When active they are easily swept from the vines with an insect net. When disturbed they either drop to the ground and play possum or fly off a few feet. They start mating toward the first of June.

The Egg.

The beetles begin to lay eggs when the first blossom buds show pink and continue to do so through most of June. Some females lay thirty-nine, but they average about twenty. Only one egg is laid in a bud, the beetle pushing it with her ovipositor into a hole made with her snout. It usually is placed among the stamens near the bases of the anthers (fig. 56). It is smooth, glistening, oblong-ovoid, pale yellowish, and nearly a fiftieth of an inch long. It hatches in three to nine days.

The Grub.

The normal hatching period is from about June 10 to July 1. The grubs develop and pupate in the blossom buds. They mature in ten to fourteen days. The mature grub (fig. 57) is whitish and has a yellowish head but no legs. It is about a ninth of an inch long.

The Pupa.

This (fig. 58) is about an eleventh of an inch long and pale yellow at first but it finally turns brown. The legs, wing pads and snout lie tightly against the body. This stage lasts about six days. When the beetle emerges it eats its way out of the bud near the calyx lobes. The beetles usually come out mostly during the first half of July.

Treatment.

Ordinary late holding of the winter flood fails to reduce this pest much. A complete flowage for two days about June 1 is effective, especially if 2 gallons of kerosene for each acre of bog is poured onto the water along the windward side soon after the vines are covered.

The beetles can be killed readily with a spray of Bordeaux mixture made up of 10 pounds of stone lime and 6 pounds of copper sulfate to 100 gallons of water, with 6 pounds of calcium arsenate and 4 pounds of fish-oil soap added. It should be used at the rate of 400 gallons to the acre, preferably in the spring after the new growth of the vines starts but before the beetles lay eggs. This is between May 20 and June 1 most years. It may be used to kill the beetles of the new brood at any time from their first appearance till mid-August, but it should be applied as soon as they appear.

Cranberry Tipworm.[66]

Vigorous vines very often recover from the attack of this insect and yield well the next year. Those that fail to do so might have been unproductive anyway. In view of this and of the fact that the effect of light or heavy cropping is carried over in the vines from one year to another, it is hard to say just how harmful the pest really is, but it tends to reduce crops and should be controlled. It infests flowed bogs much more than strictly dry ones and tends to attack Howes vines more than Early Black. Flooding kills or drives ashore many of its natural enemies and may protect the hibernating worms from winter severities. Frost often reduces an infestation greatly when it kills the cranberry tips.

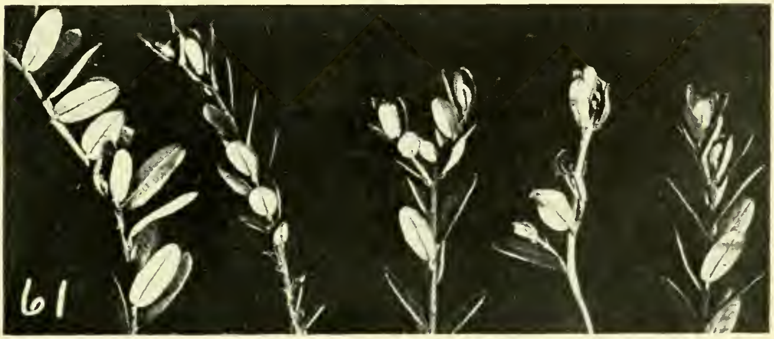


Fig. 61. Cranberry Tipworm. Cranberry uprights attacked by both broods, the branching of the tops being due to the work of the first, the cupped tips to that of the second.

Distribution and Food Plants.

The tipworm is abundant wherever cranberries are grown, causing concern in Massachusetts, New Jersey, Wisconsin and on the Pacific coast. It has been said to infest other heaths and loosestrife[67].

Character of Injury.

The first brood of maggots works mostly during the first half of June. It does little harm for it is seldom very abundant and the vines have time to recover. The second brood is much more plentiful and generally appears when the vines are in full bloom. Its work is more serious for it interferes with the development of the terminal buds that should produce the blossom-bearing growth the next year.

Both broods work wholly among the leaves at the tips of the uprights and runners. These become cupped and bunched together characteristically (fig. 59). This is due to the feeding of the worms on their inner surfaces which they rasp with a little horny process on the under side of the body. The inner leaves die (fig. 60) and sooner or later break off. New growth repairs the injury done by the first brood (fig. 61). Side buds usually develop in most of the tips attacked by the second, but these are more likely than terminal buds to produce leafy growths instead of flower shoots the next year, especially if the vines lack vigor.

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[66] *Dasyneura vaccinii* (Smith).
[67] *Lysimachia* sp.

Description and Seasonal History.

Flies and Eggs.

The adult is a delicate fly expanding less than an eighth of an inch. The male is rather dark and inconspicuous, but the female (fig. 62) has a large reddish abdomen. The female lays her eggs near the bases of the terminal leaves (fig. 63). The eggs are watery translucent with scattered reddish pigment and are about a seventieth of an inch long. They are smooth, elongate, usually slightly curved from end to end, and with rounded ends.

Worms and Cocoons.

From one to five maggots appear in each infested tip. They vary from pale yellowish to orange red and are pointed at one end (fig. 64). They have neither legs nor head. They mature in about ten days, becoming about a sixteenth ot an inch long. Those of the first brood make their cocoons in the injured tips and the flies emerge in a few days; those of the second descend to the ground when mature and there form cocoons in which they live till late the next spring, without much harm from the winter flowage even when it is held late.

The cocoons are whitish, slightly flattened cases of closely spun silk about a sixteenth of an inch long. Those of the second brood usually are attached to fallen leaves or other trash (fig. 65). The maggot changes into a brown pupa and this wriggles out of the cocoon through a slit at one end shortly before the fly emerges.

Treatment.

The maggots endure submergence longer than it is safe to have the growing vines flooded and it has not been found practicable to give them special treatment with any insecticide. Bogs that are sprayed thoroughly three or four times at regular weekly intervals with 1 quart of 40 per cent nicotine sulfate and 4 pounds of fish-oil soap to 100 gallons of water to control the first brood of the black-headed fireworm usually are freed of the tipworm[68]. Ordinary resanding every other year during the fall, winter or early spring checks the pest nicely on most bogs, but it seldom pays to sand so often if a bog has ample frost protection. The sand either smothers the worms in their cocoons or prevents the emergence of the flies. Fertilizer helps weak vines bud after the attack of the worms, especially on sand bottom.

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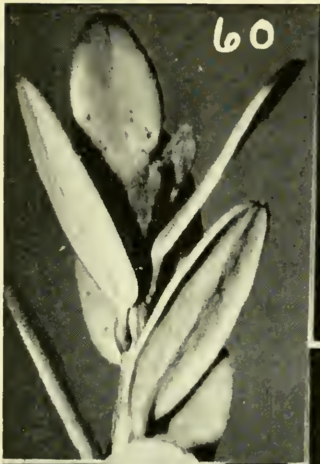
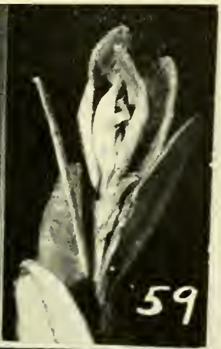
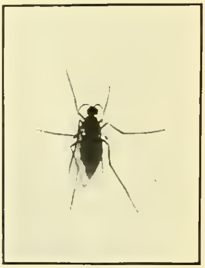
[68] See note 11, p. 11.







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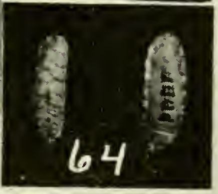
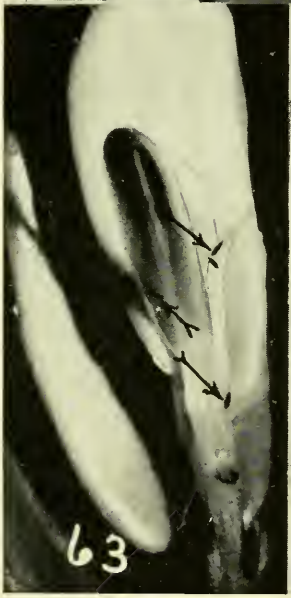
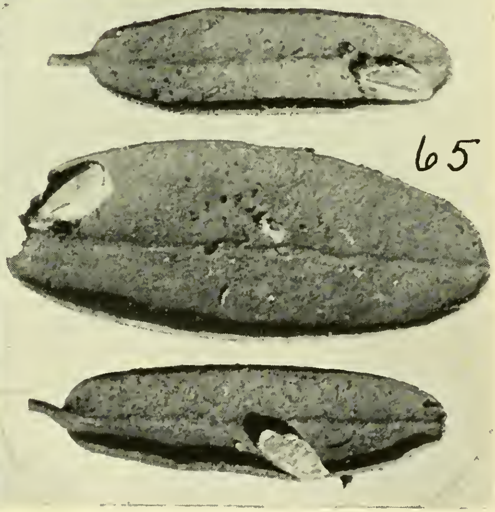






Cranberry Tipworm.

Fig. 59. Cranberry tip injured by maggots. Much enlarged.

Fig. 60. Cranberry upright with tip killed by worms of second brood. Considerably enlarged.

Fig. 62. Female fly. Much enlarged. (From U. S. Dept. Agr. Farmers' Bul. 860.)

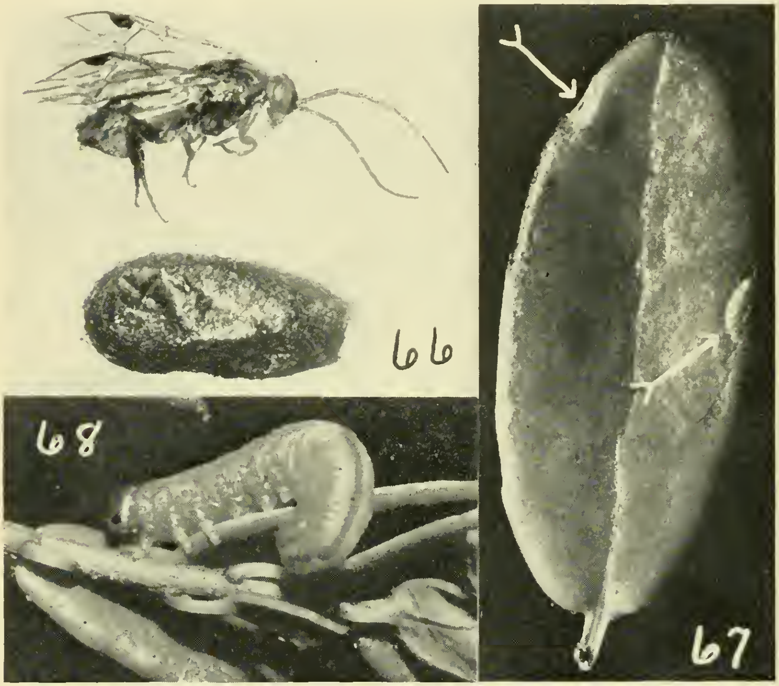
Fig. 63. Eggs in tip of cranberry upright. Much enlarged.

Fig. 64. Maggots. Much enlarged.

Fig. 65. Cocoons of second brood on fallen leaves. Much enlarged.

Cranberry Sawfly.[69]

This species occurs only on dry bogs and bogs that are not reflooded regularly. It hardly ever attracts attention, but its long feeding period probably sometimes allows it to do considerable harm. It is one of the minor drains that must be checked to make cranberry culture efficient.



Cranberry Sawfly.

Fig. 66. Cocoon and female fly. Much enlarged.
Fig. 67. Cranberry leaf with egg-pockets. Much enlarged.
Fig. 68. Worm. Much enlarged.

Distribution and Food Plants.

This insect has been found in Massachusetts, New York, New Jersey, Illinois and Wisconsin. Cranberry is its only known food plant. The worms scallop the leaves irregularly.

Description and Seasonal History.

The worms winter in rather tough cocoons of coffee-brown silk (fig. 66) among the trash on the bog floor, unharmed by the winter flood. They pupate in early May and the adults usually emerge soon after mid-May and lay eggs so that the larvae appear on the bogs again early in June. About five generations occur, the last worms usually entering their winter cocoons in mid-October. The worms develop so irregularly that the broods get mixed by late summer, all stages occurring at once.

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[69] *Pristiphora idiota* Norton.

The Egg.

The female always perches on the edge of a cranberry leaf to lay and puts her eggs in pockets she makes between the upper and lower surfaces and opening at the margin (fig. 67). The pockets usually are placed singly, but sometimes two or more are near together. One or, rarely, two eggs are placed in a pocket and often protrude a little. They are elliptical, watery greenish brown, and a little over a twenty-fifth of an inch long.

The Larva.

At first the worms are light yellowish green with the head dark brown. They grow darker with age. When mature (fig. 68) they are slightly over three-eighths of an inch long, smooth, green, and without noticeable markings except a narrow internal stripe of whitish pigment running the length of the back on each side of the heart and conspicuous through the skin. Their heads are pale greenish brown with a black dot on each side. They have six pairs of prolegs.

The Adult.

The flies (fig. 66) are a fifth of an inch long and half an inch across their expanded wings and mostly black, but the females have a broad band across the middle of the upper side of the abdomen and all its under side but the tip brownish yellow.

Treatment.

Flooding for 15 hours about June 10 or for 18 days in late September and early October is effective; so also is spraying with 6 pounds of dry lead arsenate to 100 gallons of water early in June.

3 M—3-'28. No. 1647

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

Bulletin No. 240 **January, 1928**

Factors Affecting Returns from Potatoes in Massachusetts

By Ronald L. Mighell

Information about probable prices and basic costs, both for his own farm and for other farms competing for the same markets, plays a very prominent part in the success of the farmer today. This bulletin shows the cost, in labor and materials, of growing potatoes in four different sections of Massachusetts, and suggests how the individual may use such information in studying his own farm practice.

Requests for bulletins should be addressed to the

AGRICULTURAL EXPERIMENT STATION
AMHERST, MASS.

Summary

Massachusetts growers now supply one-tenth of the estimated annual consumption of potatoes in the state.

Variations in the size of the Massachusetts potato crop have almost no influence on the price of Massachusetts potatoes.

Some farmers are meeting outside competition and securing profitable returns; others have not yet adopted improved practices or have not found it profitable to do so.

Data, from 54 Massachusetts farms, for potatoes in 1926 show variations in man labor cost ranging from 54 to 216 hours per acre.

Rates of seeding varied from 9 to 20 bushels per acre, and of manure from none to 30 tons per acre. Yields ranged from 70 to 388 bushels per acre.

The use of special potato machinery reduced the average amount of man labor in planting from 17.9 hours to 7.5 hours per acre; and in harvesting from 66.3 to 42.6 hours.

In addition to differences in rates of seeding, fertilizing, and spraying, variations in soils and previous cropping and varietal differences are important factors affecting yields on Massachusetts farms.

FACTORS AFFECTING RETURNS FROM POTATOES IN MASSACHUSETTS

By Ronald L. Mighell[1]

Assistant Research Professor of Farm Management

How Many Potatoes Should Massachusetts Grow?

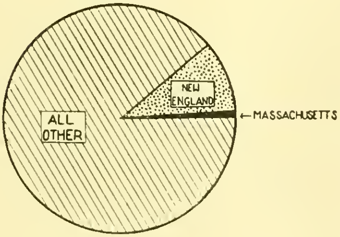
The potato crop is an important source of income on many New England farms. In Massachusetts, apples and cranberries are the only cash crops, other than market garden crops, which ordinarily exceed potatoes in value.

Massachusetts farms produced between 2 and 3 million bushels of potatoes annually from 1922 to 1926. This is estimated to have supplied only about one-tenth of the annual consumption of the people within the State. Should more have been grown? Should more be grown now and in the years to come? These questions cannot be answered definitely and at once for all farmers. The answers will vary for different individuals and different groups.

Certainly every Massachusetts farmer should ask himself several things before adding potatoes to his farm business or before changing the acreage already grown. Is this a profitable crop for me to grow now? Will it be profitable in the future?

The answers to these questions will depend upon the farmer's costs and upon the prices which he expects to receive. A mere glance at Figure 1 shows that the Massachusetts crop is very small as compared with the production of the United States, and has very little to do with the price of Massachusetts potatoes. Previous studies[2] have shown that the total production in the late crop states is one of the most important factors affecting the average price of potatoes. Hence in any study of probable future prices, attention must be paid to trends in production in the important potato growing states. Until recently, at least, the value of potatoes tended to increase faster than the general price level or the prices of other agricultural products. What may happen in the future is a question of balance between the factors affecting demand, and acreage and yield per acre as affecting supply. Should the introduction of improved machinery in Maine or New York make it profitable to expand potato acreage even in the face of increasing production and lower

Figure 1. The Contribution of Massachusetts and New England to the United States Potato Crop. (Average 1920-1925)



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[1] The author wishes to acknowledge the great assistance given in this study by Professor R. H. Barrett and Miss Marian Brown of the Department of Farm Management; and the helpful criticism of Professor J. A. Foord, head of the Department of Farm Management, and of Director Sidney B. Haskell of the Massachusetts Agricultural Experiment Station.

[2] Working, Holbrook. 1925. Factors Affecting the Price of Minnesota Potatoes. Minn. Agr. Expt. Sta. Tech. Bul. 29.
1922. Factors Determining the Price of Potatoes in St. Paul and Minneapolis. Minn. Agr. Expt. Sta. Tech. Bul. 10.

prices, or should the present lower prices of fertilizer result in increased yields of potatoes in competing areas, Massachusetts growers who could not or did not adopt similar methods would find themselves at a disadvantage.

At the present time the Bureau of Agricultural Economics of the United States Department of Agriculture and various other agencies are making extensive studies of supply and demand and probable future prices of various crops and livestock. The Bureau publishes an Agricultural Outlook report early in February which states the probable outlook for farm commodities for the coming year. This is supplemented by the *Intentions to Plant* report in March and by other special reports at other times. The New England Research Council also publishes an Outlook in February which more fully covers the New England situation. With this knowledge available the farmer has the task of adjusting his production practices to make a profit, or of turning to other crop or livestock enterprises.

The average Massachusetts potato grower generally has a farm price which is from 40 to 60 cents per bushel higher than the farm price in Maine because of differences in freight and handling charges.

TABLE 1.—Potatoes: Estimated Price in Cents per Bushel Received by Producers on Dec. 1. Average 1921-1925, Annual 1921-1926.[a]

	Average 1921-1925	1921	1922	1923	1924	1925	1926
Massachusetts	145	152	95	135	96	245	180
Maine	89	85	45	70	43	200	133
Difference	56	67	50	65	53	45	47

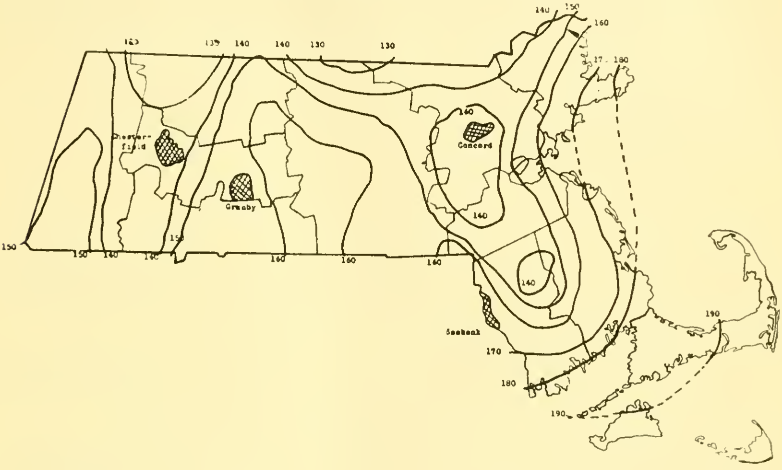
[a] U. S. Dept. Agr. Yearbook, 1926.

Table 1 gives the December 1 farm price of potatoes in Massachusetts and Maine, and the difference is in favor of Massachusetts in each year. It will be seen that the average Massachusetts grower has a very wide margin of price advantage. It is true, however, that there are many growers who are not "average," whose local prices may be different or who may live at some distance from the market. Some growers have special local outlets and are able to obtain higher prices by careful grading. Whether these advantages are sufficient to overcome the effect of lower yields, higher amounts of labor used, and other disadvantages, must be worked out by individual growers in Massachusetts for their particular situations.

The Areas Studied.

This study is directed primarily at the cost side of the potato problem. How much labor do Massachusetts farmers put into growing potatoes? How much seed and fertilizer do they use? Are they taking advantage of specialized machinery? In what ways can their practices be improved? Data are presented showing the amounts of man labor and materials used in producing potatoes on 54 farms in four areas in Massachusetts during 1926. They are taken from records secured by personally visiting 13 or 14 farms in each locality. The farms studied are located as indicated in Figure 2, which also shows the average number of days between killing frosts. The first area is in Chesterfield and Cummington in Hampshire County; the second in Granby in Hampshire County; the third in Concord in Middlesex County; and the fourth in Seekonk, Swansea, and Rehoboth in Bristol County. These areas are referred to in the text as the Chesterfield, Granby, Concord, and Seekonk areas, respectively.

Fig 2. Location of Areas Studied and Average Number of Frost Free Days.



Chesterfield Area.

The Chesterfield Area is characterized by a rolling to hilly topography with elevations on the farms visited varying from 1200 to 1600 feet. This altitude gives the area a shorter, cooler growing season than that of the others studied. The soils are extremely variable and in places very stony, but potatoes are usually grown on the heavier and more fertile land and where machinery can be used to better advantage. The amounts of labor used were greater than in the other areas, because of the stonier soils and rougher topography.

Potatoes occupied 11 per cent of the total crop land on the farms studied as compared with 3 per cent[3] for the entire town of Chesterfield. Most of the remaining acreage was in hay and forage crops. The average total crop acreage per farm was 40 acres in 1926. Dairying is the principal source of income for most of the farmers who are chiefly dependent on the land for their livelihood. The potato crop in such a farming system is an important supplementary source of cash income.

The growers of Chesterfield and Cummington are from 20 to 24 miles from their market, but the roads are good and no difficulty is experienced in trucking except from some isolated farms. Chesterfield potatoes go chiefly to Northampton and those of Cummington to Dalton and Pittsfield.

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[3] United States Census of Agriculture, 1925.

The Granby Area.

Farmers in no other area studied used so little man labor per acre of potatoes in 1926 as the Granby farmers. The elevation varies from 240 to 300 feet above sea level and the fields are relatively level and regular in shape. The light sandy loam soil is easily worked and tractors and potato machinery are easily used. The growing season of about 150 days is longer than in Chesterfield but not quite as cool.

Potatoes occupied 12 per cent of the average total crop acreage of 51 acres per farm studied in Granby. As in Chesterfield, the potato is a cash crop which fits into a more or less regular rotation with the hay and forage crops grown for dairy cows. In such rotations potatoes usually follow several years of grass.

Granby farms are favorably situated with respect to markets. It is only about 8 miles to Holyoke. In 1926 most growers sold their potatoes to buyers who came to the farm.

The Concord Area.

The potato crop in Concord supplements dairying on some farms, and on others is only one of several market garden crops and competes with them for the time and resources of the farmer. Both Cobblers and Green Mountains are grown for the Boston market about 18 miles away.

The elevation runs from 120 to 160 feet. The fields are very level and there are few stones, thus facilitating the use of machinery. The soil under the careful treatment given by the growers produces high yields.

Potatoes occupied 13.5 per cent of the crop land on the farms studied in the Concord area, as compared with 4.7 per cent[4] for all farms in the area. This area differs greatly from Chesterfield and Granby in the high percentage of crop land in other vegetable crops. Over 23 per cent of the crop land on the farms studied was in other vegetables. The farmer in Concord, in deciding how much land to put in potatoes or whether to grow them at all, has many alternatives to consider, as contrasted with the grower in Chesterfield who has little choice of other cash crops.

The Seekonk Area.

The Seekonk area differs markedly from the others. Less than 100 feet above the sea, the fields are level and the soil very light and sandy. Heavy applications of commercial fertilizer produce high yields. The growing season at Providence (about 12 miles from the area) is long, averaging 195 days for the 10-year period 1917-1926. The annual precipitation is slightly less than in the other areas. Cobblers are much more important in Seekonk, over two-thirds of the potato acreage studied being in Cobblers. No doubt they are better adapted to this area than to other parts of Massachusetts, but they apparently yield only about three-fourths as much as Green Mountains where grown on the same farms.

Market garden crops are important in this locality as in Concord, and potatoes are usually only one of many cash crops; although in some cases they also supplement dairying.

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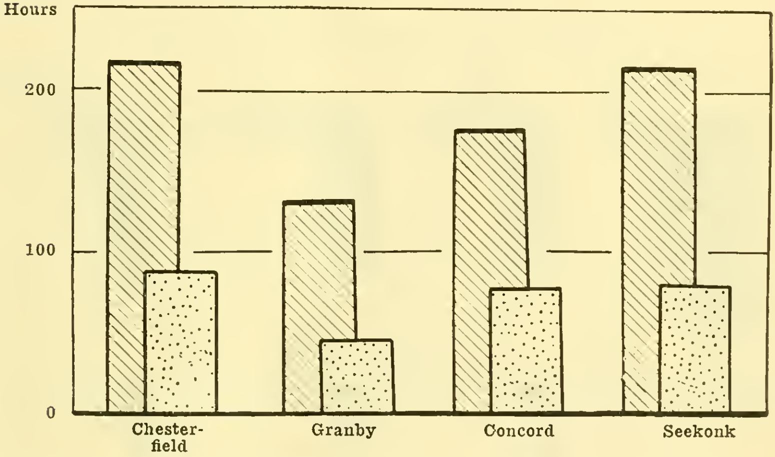
[4] United States Census of Agriculture, 1925.

The nativity of the farmer is an important factor affecting the amount of hand labor used in the Seekonk area. Many small farms are operated by men of foreign descent who either lack the capital to purchase machinery or else have enough family labor to grow potatoes without machinery.

Providence is the chief market for the potatoes and other cash crops grown in Seekonk. The larger growers have their own trucks and the smaller farmers often hire their produce trucked to market. Since so many of the potatoes are Cobblers, most of the harvesting is finished early. The prices secured in 1926 were lower than in other areas because the early market was low. Because of southern competition the grower in southwestern Bristol County has an entirely different market situation to meet in making his plans for each year's crops than the grower in other parts of Massachusetts.

Figure 3. The Maximum and Minimum Hours of Man Labor Used per Acre of Potatoes in Different Areas. All Operations.



The total labor on all farms studied in each area was rather uniformly distributed throughout the range from the minimum to the maximum.

Amounts of Labor and Materials Used per Acre for Potatoes in Massachusetts

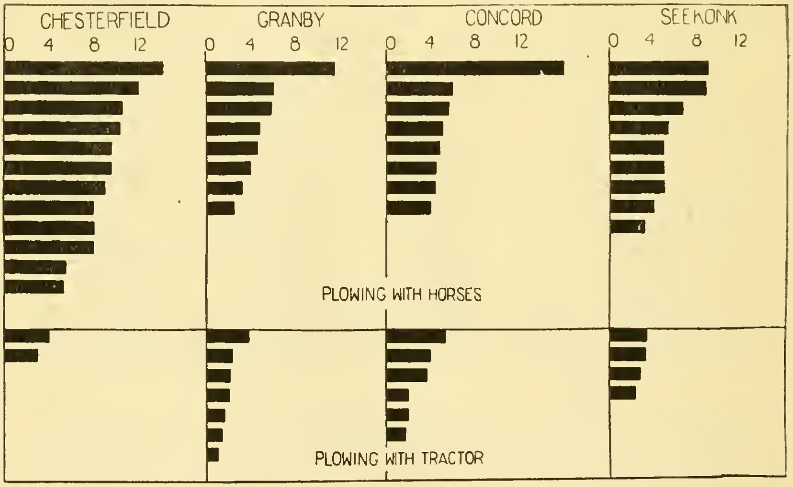
In any careful study of farm production it is essential to have a knowledge of the amounts of labor and materials used per acre. The seasonal distribution of labor on a particular crop and the probable days available for each of the crop operations is also important. With such data for his farm, a grower can forecast in advance the probable effect upon the farm resources and the net returns to his business of any proposed change in his cropping system. And by comparing the data from his farm with similar data from other farms in the neighborhood or in other regions, the farmer can see whether his production is made with a higher or lower input of the various items of labor and materials.

In all studies of this kind a wide range in the amounts of labor and materials used has always been discovered. The tables and charts set forth these differences as found in the four areas in Massachusetts, and the text points out their causes and indicates ways in which labor and materials may be conserved in growing potatoes.

Labor and Materials Used in the Chesterfield Area.[5]

The total hours of man labor per acre used in potato production in 1926 on the Chesterfield farms are shown in Table 2 and Figure 3. The man labor varied from 87 to 216 hours per acre. Some of the causes of these variations are suggested in Table 3, which shows the labor by operations. There are many factors affecting the amounts of man labor used in growing potatoes in Chesterfield. Part of these are pointed out in the discussion of the operations which follows. Some farmers are able to perform the operations more quickly than others, due to the kind of implement used, the number of times an operation is repeated, the size and slope of fields, and the stoniness of the soil.

Figure 4. Hours of Man Labor per Acre in Plowing.



The smaller, stonier fields of Chesterfield take longer to prepare. More tractors are used in the other areas.

Preparation and Planting.

The farmers of Chesterfield spend more time plowing than other Massachusetts farmers, because their fields are small, hilly, stony, and irregular in shape. Figure 4 shows the hours per acre used in plowing. A man with two horses and a 12-inch walking plow took from 5.3 hours to 14.2 hours to plow an acre. On one farm a man with a Fordson and a 16-inch plow used 3 hours to plow an acre; and on another with the same kind of equipment it took 4 hours.

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[5] Hours of horse and tractor work are not given. For the most part, they closely parallel the hours of man labor.

TABLE 2.—Potatoes: Acres per Farm, Yield per Acre and Man Labor per Acre.

	Chesterfield				Granby			
	No. of Farms	Minimum	Average	Maximum	No. of Farms	Minimum	Average	Maximum
Acres per farm	13	1	4.5	13	14	3.5	6.2	17
Yield—bushels per acre	13	127	241.8	335	14	100	175.8	262
Labor—total hours per acre	13	87.3	127.3	216.0	14	45.5	73.1	129.7

TABLE 3.—Hours of Man Labor Used per Acre of Potatoes, by Operations.

Operation	Chesterfield				Granby			
	No. of Farms	Minimum	Average	Maximum	No. of Farms	Minimum	Average	Maximum
Manuring—hours	10	2	13.1	16.6	12	1.2	6.6	13.7
Plowing—								
hours with horses	12	5.3	7.7	14.2	8	4.0	4.3	6.0
hours with tractor	2	3.0	3.7	4.0	7	1.4	2.0	3.7
Picking stone—hours	11	1.6	6.1	7.4	1	0.6	0.6	0.6
Disking—								
hours with horses	8	2.0	5.0	14.4	4	1.0	2.5	6.0
hours with tractor	5	1.2	3.0	4.0	7	0.6	1.1	2.3
number of times	*13*	*1*	*3.8*	*6*	*11*	*1*	*1.6*	*2*
Smoothing—								
hours	8	0.5	1.5	2.5	10	0.7	1.7	4.6
number of times	*8*	*1*	*1.4*	*3*	*10*	*1*	*1.2*	*2*
Treating and cutting seed—								
hours	12	4.8	7.9	15.2	14	1.2	5.5	8.3
Planting—hours	13	2.0	5.0	9.6	14	2.1	4.3	9.6
Rolling—hours	5	1.0	1.3	1.6	10	0.4	0.6	1.0
Fertilizing—hours	4	1.0	2.1	4.5	7	0.5	0.9	1.6
Weeding—								
hours	10	1.2	3.0	9.0	9	0.3	1.6	5.7
number of times	*10*	*1*	*2.9*	*6*	*9*	*1*	*1.9*	*4*
Cultivating—								
hours	13	3.0	7.7	24.0	14	4.6	9.4	17.7
number of times	*13*	*2*	*4.4*	*10*	*14*	*4*	*6.2*	*12*
Hoeing—hours	4	3.3	7.6	16.0	4	0.7	6.6	11.4
Spraying—								
hours	13	1.0	8.6	20.0	13	2.0	3.8	6.8
number of times	*13*	*1*	*4.2*	*10*	*13*	*1*	*3.7*	*6*
Harvesting—hours	13	29.6	67.8	132.0	14	14.2	36.1	68.6
Grading—hours	6	9.1	24.0	48.0	..	...	...	...

The potato fields received manure on all except three farms in this area. Labor in hauling manure varied chiefly with the number of loads hauled. The method of handling also made a difference. Some farmers did not have spreaders and hauled in carts and spread by hand. On one farm the manure was hauled out in winter and piled and spread the following spring. Most of the work on manure is done at times when it does not interfere with other crop work.

Stone picking is an annual operation on most of these hill farms. The stones must be removed every time a field is plowed. From 2 to 4 hours of man labor per acre usually seems to be sufficient.

Differences in labor in disking and smoothing were largely due to the number of times the operations were performed. The usual practice is to double disk from one to three times and then to run the smoothing harrow over the ground once before planting. Other causes of variation were size of field, distance to field, and width of implement. One farm had a very high labor input because the land was disked twenty times.

Not all Chesterfield growers treated their seed. The time used by those who did depended on the equipment and its convenience for doing the work. Time used in cutting seed varied greatly with the individual. One man who used a fixed knife and had the potatoes in an inclined box so that they were conveniently reached was able to cut 5 bushels an hour. Those who used No. 2 seed[6] did not do as much cutting.

Figure 6 shows the average amount of labor used in planting by different methods for all areas. Other variations were caused by such factors as the size and shape of the field, the convenience of seed and fertilizer, and freedom from delays or accidents. Some of the growers used additional fertilizer, either before planting or afterward.

Cultivating and Spraying.

About half the potato acreage in Chesterfield was rolled once or twice after planting in 1926. The practice on a few farms is to run a ridger over the field and then roll down the ridges. This is repeated, usually just as the potatoes are breaking the ground.

The one-horse weeder was commonly used two or three times before cultivating. The number of times over caused large differences in labor in cultivating. It was not greatly different with a one or two horse cultivator. Some extra cultivating was done to get rid of weeds. The last cultivation was commonly a hilling operation with either the ridger or horse hoe or with wings placed on the cultivator.

Some farmers spent a certain amount of time in hoeing and pulling weeds. This labor is usually done at odd times and does not conflict with other operations.

Spraying time was more variable than almost any other operation. Both the number of times and the labor each time differed greatly. There was very little disease in Chesterfield in 1926 and the presence or absence of spray may not have affected yields in that year. Hand spraying in some cases increased the labor used. The man labor for spraying on one farm was higher than on the others because water had to be hauled a long distance. The use of a commercial power duster on two other farms greatly reduced the labor.

Harvesting.

Harvest labor includes digging, picking up, hauling to barn or house, sorting, and grading. The use of the hook in digging accounts for the large number of hours of man labor for harvesting on two farms. All others used a potato digger. Time used with the digger was affected by the presence of stones and weeds, the number of delays, and the length of time over which the digging was spread.

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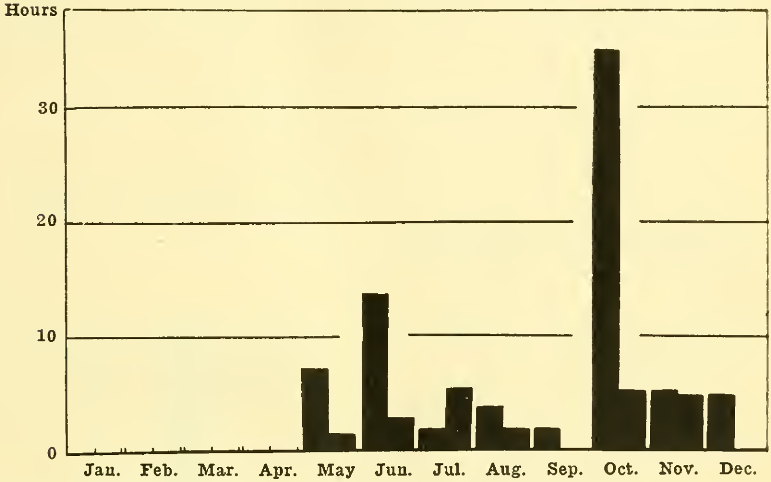
[6] No. 2 seed differs from No. 1 only in size. It may be from certified fields.

A grader was used on two farms, and much hand grading was done on some others. These farms supplied a special market and secured a higher price for carefully graded potatoes. Attention was paid to grading out the cull potatoes at digging time on all farms. This was not difficult in 1926, for the crop was well matured.

Figure 5. Distribution of Man Labor per Acre by Half-Months for 6.5 Acres of Green Mountains on Farm 1 in Chesterfield, 1926.



Potatoes in Chesterfield are planted in May or early June. Harvest falls in the first half of October. The labor in November and December represents hauling manure and plowing for next year's crop.

Seasonal Distribution.

Figure 5 shows the distribution of man labor on farm 1. Considerable variation from this distribution was found but this is fairly typical for potatoes in Chesterfield. The season is from one to two weeks later than in the other areas studied. There are no serious conflicts with other crops unless a considerable acreage is grown.

Materials Used.

More seed was used in the Chesterfield area than anywhere else. The usual rate of seeding was about 18 bushels per acre. Table 4 shows that the range about this rate was not very great. Farms 10 and 13 used No. 2 seed and therefore did not plant as many bushels. Seed planted on these farms in 1926 was home-grown.

Fertilizer applications varied from 600 to 2000 pounds per acre. Nearly all was 5-8-7 potato fertilizer. On farms 1 and 8 "double strength" or 10-16-14 fertilizer was used. This is given in Table 3 in terms of its 5-8-7 equivalent.

TABLE 4.—Materials Used per Acre of Potatoes, Chesterfield Area, 1926.

Farm Number	Acres per Farm	Yield per Acre	Seed Bu.	Fertilizer Lbs.	Manure Tons	Bordeaux Lbs.	Lead Arsenate Lbs.	Corrosive Sublimate Oz.
8	2.25	127	20.0	1776	8.8	8.8	4.4	1.3
3	3.00	167	17.0	1400	....	50.0	....	....
12	2.50	200	18.0	600	20.0	32.0	6.6	4.0
5	1.25	208	18.0	1600	16.0	112.0	8.0	...
1	6.50	218	18.0	1600	15.0	61.5	3.7	4.9
2	8.00	231	18.6	1800	....	100.0	10.0	6.0
6	13.00	250	17.0	2000	....	1.0	....	6.1
13	3.00	250	11.6	1666	16.6	80.0	8.0	8.0
4	8.00	262	18.0	1500	3.8	100.0	10.0	...
10	3.50	271	13.0	1000	18.0	280.0	6.8	4.6
9	2.50	280	15.6	1200	30.0	....	4.8	6.4
11	4.00	312	15.0	1700	20.0	80.0	7.5	3.7
7	1.00	335	19.0	1400	25.0	....[a]	....	...
Averages[b]	4.50	242	16.9	1610	14.8	86.9	7.5	5.4

[a] Hired dusting. Amount not given.

[b] Averages for acres on which applied.

Applications of manure varied from none on farms 2, 3, and 6, to 30 tons per acre on farm 9.

The amounts of spray material used are shown in Table 4. All but three growers mixed their own Bordeaux and lead arsenate on the farm. A commercial dust was used on farms 3, 6, and 7.

Labor and Materials Used in the Granby Area.

The man labor used on the Granby farms varied from 45 to 130 hours per acre. This was considerably less than in the other areas studied. As compared with Chesterfield, there were more tractors in use and the fields are more regular and have fewer stones. Less time was spent in performing most of the field operations. Only one grower did not use a digger in harvesting and very little time was spent in grading, a large percentage of the potatoes being sold at the farm just as they came from the field. Less time per acre was used in picking up, owing to the lower yield.

The following discussion of the individual operations throws some light on other causes of variation in the labor input.

Preparation and Planting.

Considerably less time was used in drawing manure on the Granby farms than on the hill farms of Chesterfield. This is explained by the greater number of manure spreaders in use, only one farm in Granby being without a spreader; and by the fact that the manure was handled only once in Granby and on some of the hill farms it was hauled out in the winter and later rehandled.

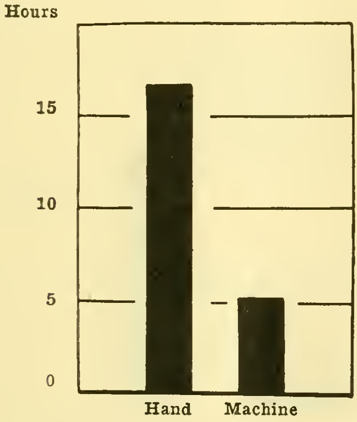
The range in hours spent in plowing an acre in Granby is shown in Figure 4. With two horses and a walking plow it took from 4 to 6 man hours to plow an acre. On one farm, 11.4 man hours were used, but the land was plowed twice. With a tractor it took from 1.4 hours to 3.8 hours to plow an acre.

Stone picking was reported on only one farm in Granby. This freedom from stones is an important natural advantage.

The usual preparation of the land after plowing in Granby consisted in double disk harrowing once or twice and smoothing once with a two section spike-tooth harrow. Those farmers who owned tractors used the double action disk harrow. The smoothing harrow was usually horse-drawn.

About half the growers in Granby treated their seed with corrosive sublimate in 1926. The time used is included with cutting in Table 3. Time for cutting varied with the method used and the kind of seed. Some of the No. 2's were cut only once if at all.

Figure 6. Average Hours of Man Labor Used for Planting by Hand and by Machine.



Out of fourteen farms studied in Granby, five used a one-man planter, eight used a two-man, and one planted by hand. Figure 6 shows the average time used in all areas for planting by different methods. Whether the two-man planter is enough more accurate to warrant the use of another man is a matter which each farmer must determine for himself. The saving in man hours as shown in these records was from 1 hour to 5 hours per acre. When the one-man planter is carefully operated and the seed evenly cut there are few skips; but when it is not, or when the seed is uneven, there may be many.

Time spent in spreading additional fertilizer is not included under planting. Half the farmers applied additional fertilizer a week or ten days after planting.

Operations After Planting.

On all but four of the farms, the potatoes were rolled once after planting and gone over with the weeder once or twice before cultivating. The most common number of cultivations was six, although the range was from four to twelve.

Both one and two-horse cultivators were used, frequently on the same farm. The two-horse cultivators were generally riding cultivators. More cultivating was done with the two-horse than the one-horse machines. The last cultivation was commonly shallow without much hilling.

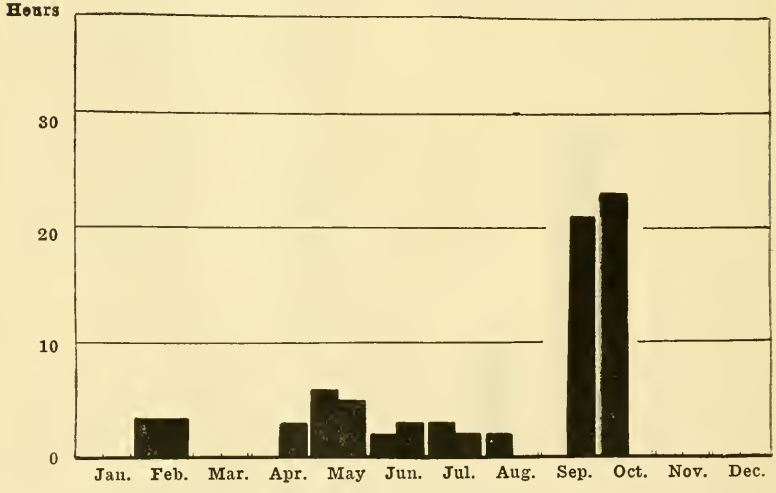
The number of times sprayed varied from none to 6. One farmer used a hand duster and another employed a 100-gallon sprayer. The usual type of sprayer, however, was a 50-gallon traction sprayer.

Harvesting.

Harvesting included digging, picking up, and drawing from the field. Practically no sorting or grading was done in 1926. The time varied from 14.2 man hours per acre to 66.6 hours. The minimum amount is explained by the very low yield of 100 bushels per acre. The yield on the high labor farm was exceeded by only one other farm, the harvest was somewhat prolonged, and the potatoes were dug by hand. All other farms used a digger.

The chief causes of variation in digging time were probably the length of time over which the digging extended and the kind of labor used at harvest. Less time was used when the potatoes were all dug in a short period. Some growers exchanged labor and were able to save time by thus using a larger crew.

Figure 7. Distribution of Man Labor per Acre by Half-Months for 6 Acres of Green Mountains on Farm 21 in Granby, 1926.



Much manure hauling comes in the winter months in Granby. Planting is done about May 15. Harvest runs from September 15 to October 15.

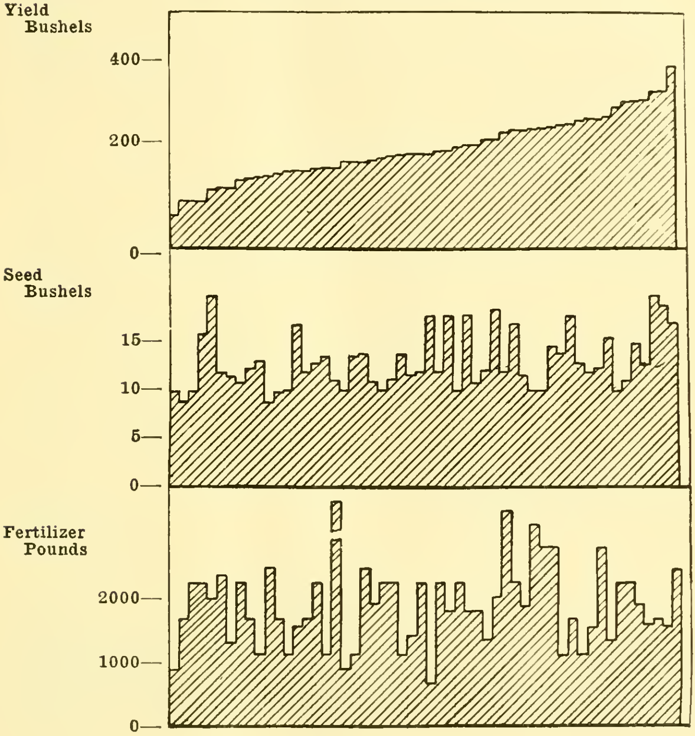
Seasonal Distribution.

Figure 7 shows the seasonal distribution of man labor on farm 21. This is a rather typical distribution in the Granby area. The labor in February represents manure hauling. The other labor before harvest is spread rather uniformly through May, June, and July. It conflicts to some extent with work on corn and hay during this period. The harvest on farm 21 was begun about the middle of September and spread over a month. For those in Granby who grow Cobblers, the harvest begins in August.

Materials Used.

The amounts of seed, fertilizer, and manure used per acre in all areas are compared with the yield per acre in Figure 8. Seed planted in Granby varied from 8.7 to 14 bushels per acre. The chief cause for the variation was the amount of No. 2's planted. Those farmers who planted less than twelve bushels per acre used part or all No. 2 potatoes.

Figure 8. Yields of Potatoes and Accompanying Inputs of Seed and Fertilizer.



The 54 farms are arrayed in order of yield with the accompanying amounts of seed and fertilizer. For example, the seed and fertilizer used on the farm with lowest yield are directly below the first portion of the yield graph. The apparent lack of association between yield, and seed and fertilizer, is due to other factors such as manure, spraying, soil, and previous cropping not included in the chart.

Applications of fertilizer ranged from 1000 pounds per acre on several farms to slightly more than 2200 on farm 24. Double strength (10-16-14) was used on farms 15, 16, 23, 25, and 26 either in part or altogether. This is expressed in terms of 5-8-7 in Table 5 for purposes of comparison. All other fertilizer was of the 5-8-7 grade.

Applications of manure ranged from none on farms 16 and 18 to 25 tons per acre on farm 27.

Only about half the growers treated their seed in 1926. Corrosive sublimate was used except on farm 27, where the formalin treatment was employed. A few farmers mixed their own spray, but the common practice was to purchase a commercial Bordeaux in the powdered form and add water and lead arsenate. The exact amounts are shown in Table 5.

TABLE 5.—Materials Used per Acre of Potatoes, Granby Area, 1926.

Farm Number	Acres per Farm	Yield per Acre	Seed Bu.	Fertilizer Lbs.	Manure Tons	Bordeaux Lbs.	Lead Arsenate Lbs.	Corrosive Sublimate Oz.
25	4.0	100	9.0	1500	10.0	25.0	5.0	...
15	6.0	150	12.5	1500	7.5	16.6	16.6	...
24	17.0	154	8.7	2205	2.5	52.9	4.4	...
23	5.0	160	9.9	1500	14.2	....	10.0	...
17	5.0	165	10.0	1000	7.5	24.0	8.0	...
26	7.0	171	12.9	2000	10.0	....	....	...
21	6.0	173	13.7	1000	12.0	33.3	8.3	...
14	4.0	187	13.7	1000	15.0	....a	....	...
18	8.0	187	14.0	2200	....	25.0	....	3.2
20	3.5	189	11.0	1714	14.8	....	7.4	...
16	8.0	198	11.3	2000	....	84.00	9.0	4.1
22	4.0	199	14.0	1000	13.5	25.0	4.0	3.0
27	3.5	200	11.8	1285	25.0	28.6b	....	...
19	5.5	262	14.0	1000	12.0	72.7	9.1	...
Averagesc	6.18	176	11.6	1781	9.9	43.9	7.8	3.5

a Hired dusting, amounts not given.
b Dust, not included in average.
c Averages for acres on which applied.

Labor and Materials Used in the Concord Area.

The variation in man labor for potatoes on 14 Concord farms was from 75 to 175 hours per acre. In general, it can be seen that more labor was used in Concord than in Granby and somewhat less than in Chesterfield. There seems to be some increase in all the operations.

Preparation and Planting.

Reference to Figure 4 shows that the time taken to plow an acre with horses was from 4 to 6 hours with one extreme case of 16 hours. On this farm there was only one acre in potatoes and this was a very stony sod. Nearly all the potato fields in this group are more difficult to plow and cultivate than those in Granby.

Operations before planting were not much different from those in Granby or Chesterfield. More labor was spent cutting seed than in Granby. It took longer to plant an acre. On three farms the ground was marked off with a one-horse marker before using the planter. On two farms planters were not used, the land being marked off, fertilizer applied, and potatoes dropped by hand. Another farm used a large amount of time by placing each seed potato separately.

Operations After Planting.

Rolling was not practiced. A plank drag was used on several farms. A few applied additional fertilizer after planting. The weeder was used from 1 to 4 times before cultivating.

Six was the most common number of cultivations given, although there were as many as 14. Both one and two-horse cultivators were used. The last cultivation was frequently a hilling operation for which a two-horse ridger was employed. Much time was spent in hand hoeing and pulling weeds.

TABLE 6.—Potatoes: Acres per Farm, Yield per Acre and Man Hours per Acre.

	Concord				Seekonk			
	No. of Farms	Minimum	Average	Maximum	No. of Farms	Minimum	Average	Maximum
Acres per farm	14	1	7.6	35	13	3	6.3	10
Yield—bushels per acre	14	100	225.6	388	13	70	218.3	314
Labor—total hours per acre	14	75.5	111.9	175.3	13	78.2	122.1	167

TABLE 7.—Hours of Man Labor per Acre of Potatoes, by Operations.

Operation	Concord				Seekonk			
	No. of Farms	Minimum	Average	Maximum	No. of Farms	Minimum	Average	Maximum
Manuring—hours	8	5.0	9.6	12.0	4	3.7	10.0	15.3
Labor on rye—hours	..	...	...	...	9	2.2	4.8	6.3
Plowing—								
hours with horses	8	4.0	6.7	16.0	9	3.2	5.6	9.1
hours with tractor	6	2.0	2.6	5.3	4	2.4	3.0	3.4
Picking stone—hours	4	4.0	8.9	13.7	1	1.3	1.3	1.3
Disking—								
hours with horses	8	2.0	11.7	18.0	8	0.8	2.6	4.6
hours with tractor	6	0.8	2.0	4.0	4	1.2	2.4	4.4
number of times	*14*	*1*	*2.7*	*4*	*12*	*1*	*2*	*4*
Smoothing—								
hours	7	0.5	0.8	2.0	11	0.5	1.2	4.2
number of times	*7*	*1*	*1*	*1*	*11*	*1*	*1.3*	*4*
Treating and cutting seed—								
hours	14	3.0	8.1	10.5	13	4.8	8.5	16.9
Planting—hours	14	2.0	6.5	15.0	13	3.3	8.9	21.2
Planking—hours	3	0.7	0.9	2.0	7*a*	0.6*a*	1.4*a*	2.2*a*
Fertilizing—hours	4	0.5	0.9	1.0	6	1.1	2.9	6.4
Weeding—								
hours	12	0.4	1.7	6.8	12	0.5	2.7	6.8
number of times	*12*	*1*	*1.9*	*4*	*12*	*1*	*2.4*	*5*
Cultivating—								
hours	14	3.5	10.7	27.4	13	4.0	9.4	15.0
number of times	*14*	*3*	*6.3*	*14*	*13*	*3*	*5.0*	*7*
Hoeing—hours	10	1.3	6.9	24.0	9	3.0	9.2	19.1
Spraying—								
hours	14	1.4	4.2	15.4	13	0.6	4.6	8.0
number of times	*14*	*1*	*3.4*	*7*	*13*	*1*	*2.1*	*4*
Harvesting—hours	14	24.6	40.5	103.0	13	40.0	60.6	99.5
Grading—hours	9	6.8	20.1	48.0	..	...	...	...

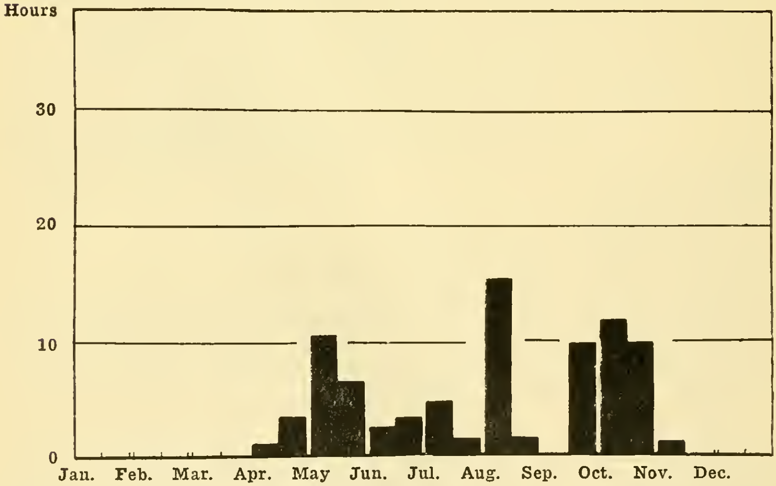
a Smoothing Harrow.

Most Concord farmers sprayed or dusted from two to four times in 1926. The time varied with the method used and the number of applications. A hand duster was used on four farms. The time also depended on the convenience of mixing the spray material, the distance to the field, and the capacity of the sprayer. The sprayer on one farm was a 200 gallon orchard sprayer with a motor. The motor was troublesome and the hours used were increased.

Harvesting.

Harvesting included the same operations as reported in the other two areas, but in addition, much more time was devoted to sorting and grading. The growers in Concord are well paid for the labor spent in sorting, for in most cases they have special market outlets and secure a premium for well graded potatoes.

Figure 9. Distribution of Man Labor per Acre by Half-Months for 15 Acres of Green Mountains and 8 Acres of Cobblers on Farm 41 in Concord, 1926.



These potatoes were planted in April and May; cultivated in June and July; sprayed from June 10 to Sept. 1.; and harvested in August (Cobblers) and from September 15 to October 31 (Green Mountains). A tractor and specialized potato machines were used.

Seasonal Distribution.

Figure 9 presents the seasonal distribution of man labor for potatoes on farm 41. On this farm 15 acres of Green Mountains and 8 acres of Cobblers were grown. The peak in early August was due to the digging of the Cobblers. Apples are an important crop on this farm and the harvest labor on the two crops interferes to some extent. This is a representative distribution on a good farm in this area.

Materials Used.

The quantities of seed, fertilizer, and other materials used on each farm are given in Table 8. The rate of seeding varied from 10 bushels to 20 bushels per acre with 12 bushels representing the most common rate. Practically all the seed was certified Maine or other northern-grown seed. Less No. 2 seed was used than in the other two areas. More Cobblers were planted here than in Granby.

Fertilizer applications averaged more and less manure was used here than in the western areas. There is less livestock to furnish the manure and more demand for it from market gardeners. The most common fertilizer application was about 2000 pounds per acre, although the range was from 800 to 2500 pounds. The 5-8-7 was used on all farms except 29, 37, and 41, which applied a 5-8-10 mixture. Those farmers who used manure applied from 8 to 20 tons per acre.

Both dusts and wet sprays were used for covering the vines. The Bordeaux was usually a commercial mixture, although some growers mixed their own. One or two growers sprayed only with lead arsenate. Only 5 out of the 14 treated their seed with corrosive sublimate before planting.

TABLE 8.—Materials Used per Acre of Potatoes, Concord Area, 1926.

Farm Number	Acres per Farm	Yield per Acre	Seed Bu.	Fertilizer Lbs.	Manure Tons	Bordeaux Lbs.	Lead Arsenate Lbs.	Corrosive Sublimate Oz.
31	5.0	100	10.0	2000	....	30.0*a*	....	...
40	1.0	100	16.0	2000	....	10.0*a*	....	...
30	2.25	129	11.5	1111	15.0	88.8*a*	....	...
39	2.6	152	13.3	1000	20.0	20.9	6.1	...
37	6.0	157	12.0	1500	20.0	....	3.3	4.0
35	4.0	188	10.0	800	....	75.0*a*	....	...
29	3.0	200	12.0	2000	....	50.0	....	2.6
36	35.0	214	10.0	2000	....	5.7	5.7	...
33	9.0	230	12.2	1222	....	....	10.0	...
41	23.0	258	14.8	2500	....	217.3	26.1	5.0
34	8.0	275	12.0	1375	18.0	18.7	9.4	2.5
38	1.0	300	10.0	2000	20.0	125.0*a*	....	...
32	3.0	333	20.0	1500	8.3	83.3*a*	....	...
28	3.5	388	17.1	2200	10.0	109.7	6.8	5.7
Averages*b*	7.6	226	12.2	1871	16.3	79.1	11.7	4.3

a Dust, not included in average.
b Averages for acres on which applied.

Labor and Materials Used in the Seekonk Area.

The farms from which records were secured lie in the southwestern part of Bristol County not far from Providence, Rhode Island. More Cobblers than Green Mountains are grown here, although the Green Mountains yield more per acre. The hours of man labor used per acre on these farms ranged from 78 to 214 per acre, and averaged about the same as for the Chesterfield farms. The soil is freer from stones than in Chesterfield but more hand labor was used in planting, spraying, and harvesting, particularly on certain farms, and this increased the average input of labor. Some of the principal operations are reviewed in the following discussion.

Preparation and Planting.

Tractors were used for plowing on about a third of the farms as indicated in Figure 4. Plowing with two horses and a 12-inch walking plow took longer than usual on the two high labor farms because both the farmers and the horses were old and did not work rapidly.

Barnyard manure was applied on only four of the farms. This is a market garden section with little livestock and manure is at a premium. The common practice is to grow rye as a cover crop and plow it under the following spring. Most of the land is kept in continuous cultivation, sometimes in potatoes alone, and as soon as the potatoes or other crop is harvested in late summer, it is disk-harrowed and seeded to rye.

The land was commonly double-disked twice and smoothed with a smoothing harrow once. The practice was not essentially different from that in other places. None of the seed was treated with corrosive sublimate or formalin, and was ready for the planter as soon as cut.

Two growers used a one-man planter, six used a two-man planter, and five planted by hand. The usual operations in hand planting included furrowing, fertilizing, dropping, and covering. Great pains were taken in placing the seed pieces on the high labor farm, which accounts for the large amount of time spent. The hours of man labor in planting are shown in Table 7.

Operations After Planting.

Following the planting the land was commonly gone over with the smoothing harrow once and then with a weeder from one to four times. About one-half of the farmers applied extra fertilizer. Most growers cultivated 5 or 6 times with a one-horse cultivator. A considerable amount of odd time was spent in hoeing and pulling weeds.

Very little spraying was done on this group of farms in 1926. Only two growers used Bordeaux and the usual number of sprays was one or two of lead arsenate.

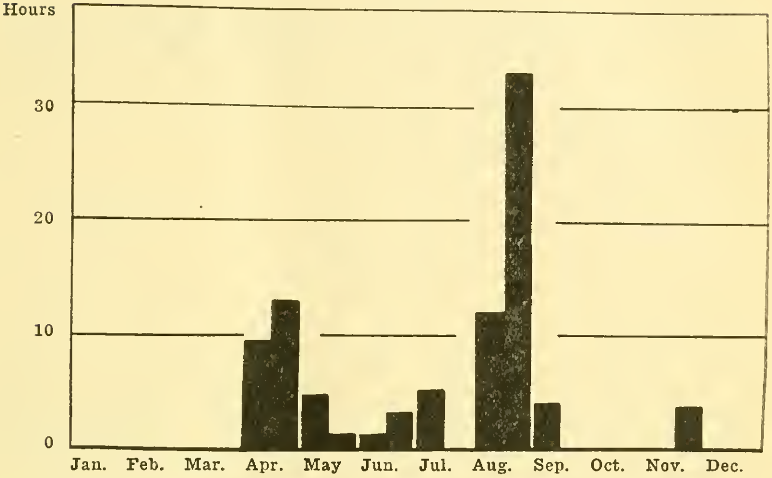
Harvesting.

Time spent in harvest ranged from 40 to 99 hours of man labor per acre. Most of the extremely high amounts were caused by hand digging. The harvest labor was somewhat higher than in other sections because it included sorting and barreling, which was usually done in the field.

Seasonal Distribution of Labor.

The seasonal distribution of man labor is shown by half-month periods in Figure 10 for farm 44. Only Cobblers were grown on this farm and the harvest labor all came in August and early September. The season is much earlier in southern Bristol County than in the other areas and the planting is largely done in April and the first half of May. This is a typical distribution for those who grow only Cobblers. For those growers who also have Green Mountains, the harvest period would be lengthened.

Figure 10. Distribution of Man Labor per Acre by Half-Months for 8 Acres of Cobblers on Farm 44 in Seekonk, 1926.



Cobblers in Seekonk are planted in April and nearly all harvested by September 1.

Table 9.—Materials Used per Acre of Potatoes, Seekonk Area, 1926.

Farm Number	Acres per Farm	Yield per Acre	Seed Bu.	Fertilizer Lbs.	Manure Tons	Bordeaux Lbs.	Lead Arsenate Lbs.
48	5.0	70	10.0	800	....	....	4.0
51	3.3	129	12.1	2121	....	....	30.0
53	5.5	145	10.9	2000	5.4	....	9.1
46	9.0	183	11.1	4000	58.3[a]	55.5[b]	....
42	10.0	193	10.0	2000	....	....	10.0
49	3.0	206	12.0	2000	....	....	....[c]
54	5.0	220	10.8	1600	....	....	60.0[d]
43	8.0	247	12.0	3000	....	....	5.0
47	10.0	253	10.0	2800	....	....	10.0
50	7.0	254	10.0	2500	....	35.7	8.6
44	8.0	276	12.5	2500	1.2	....	20.6
52	4.5	311	11.1	2000	....	....	5.5
45	3.5	314	12.8	1428	6.0	....	7.1
Averages[e]	6.3	218[f]	11.0	2389	3.6	35.7	10.6

[a] Abnormal, not included in the average.

[b] Dust, not included in average.

[c] Hired spraying, amount not given.

[d] Commercial mixture, not included in average.

[e] Averages for acres on which applied.

[f] Cobblers, 204.4 bu. per acre; Green Mountains, 248.4 bu. per acre.

Materials Used.

The materials used in this area differ from those in Concord. Rye is seeded as a cover crop, practically no Bordeaux is used, almost no manure is spread, and slightly more fertilizer is applied.

From 10 to 13 bushels of certified seed were planted per acre. Ten bushels were the most common rate. The range was also less than in other areas.

Fertilizer applications ranged from 800 pounds on farm 48 to 4000 pounds per acre on farm 46. All the fertilizer was 5-8-7 except on farms 53 and 54, which used 4-8-4 and 4-6-10, respectively.

About two bushels of rye is the usual rate of seeding for the cover crop, to be turned under the following spring.

Further Suggestions for Reducing Costs and Increasing Returns

Potato Machinery.

Farmers are interested in knowing the acreage of potatoes which will justify investment in machinery. Tables 10 and 11 will be of assistance in solving this problem on particular farms. Rates for depreciation and repairs based on estimates secured from 69 farmers in 1925 are applied to current retail prices of potato machines and the annual cost per acre for different acreages per farm are calculated. This is based on the assumption that the life of the machines will not vary greatly with small differences in acreage.

TABLE 10.—Estimated Machine Costs of Special Potato Machinery.[a]

	2-man Planter	1-horse Sprayer	Traction Digger
Estimated Years Life	16.7	8.0	14.2
Retail Price, New, Feb. 1, 1927	$130.00	$175.00	$125.00
Annual Depreciation	$ 7.79	$ 21.88	$ 8.80
Estimated Annual Repairs	5.05	11.90	6.46
5% Interest on Investment	3.44	4.92	3.34
Annual Cost per Machine	$ 16.28	$ 38.70	$ 18.60
Annual Cost per Acre for Different Acreages (b)			
2 Acres—	$ 8.14	$ 19.35	$ 9.30
3 Acres—	5.43	12.90	6.20
4 Acres—	4.07	9.68	4.65
5 Acres—	3.26	7.74	3.72
10 Acres—	1.63	3.87	1.86

[a] Table based on estimates from 69 growers for the crop year 1925.

[b] Based on the assumption that small changes in acreage do not materially affect the years life of the machines.

The average differences in hours of man labor used on 120 farms in 1924 and 1925 in planting and harvesting by machine and hand methods are shown in Table 11. Assuming that the difference is the average amount of labor that could be saved by the use of machinery and applying a cost rate to this labor, a partial solution is obtained for the problem of when to buy machinery. For example, if labor is worth 40 cents per hour and a planter will save 9 hours of man labor, the saving will amount to $3.60 annually. At this rate it would be necessary to grow nearly 5 acres to pay for the planter by the saving in man labor. There are, of course, other things to consider. If labor is scarce and cannot be hired, the machine may be indispensable; on the other hand, if there is plenty of cheap labor available, the use of machinery may not be economical. Quite frequently several farmers own a planter, sprayer, or digger jointly and thus reduce the individual expense. There were only eight out of the 54 farms studied in 1926 on which the planter was not used. It was either owned or hired by the other 46 farmers.

TABLE 11.—Differences in Labor per Acre for Planting and Harvesting by Different Methods on 120 Farms (1924-1925).

	Method	Number of Farms	Average Area per Farm (Acres)	Average Yield per Acre (Bushels)	Average Hours per Acre	
					Man	Horse
Planting	Hand	46	2.23	186.83	17.89	9.1
	Machine	74	6.3	186.5	7.5	6.1
Harvesting	Hand	39	1.88	184.9	66.3	11.7
	Machine	81	6.16	186.7	42.6	10.4

Varieties of Potatoes.

The acres of Green Mountains and Irish Cobblers grown in Concord and Seekonk are shown in Table 12. Cobblers are most important in Seekonk and less so in Concord. The answer to the query as to which is more profitable depends on two things: average yield per acre of each variety over a period of years and average price received. The table gives a summary comparison as to yields of these varieties where grown on the same farms in the Seekonk and Concord areas. This is for only one year, but is suggestive of the amount of thought and study that growers might well give to this problem. With such a large difference in yield, and prices about the same, more Green Mountains might profitably be grown, provided there is no great labor interference with other enterprises.

TABLE 12.—Yields of Green Mountains and Cobblers in the Concord and Seekonk Areas, 1926.

	Concord		Seekonk	
	Green Mts.	Cobblers	Green Mts.	Cobblers
No. of Farms	8	8	7	7
Acres in Potatoes	91.75	14.6	25.7	56.1
Av. Yield per Acre (bu.)	240.4	169.8	235.4	192.5
Fertilizer per Acre (lbs.)	1687.5	1687.5	1875.0	1875.0
Manure per Acre (tons)	7.3	7.3	11.4	11.4
Seed per Acre (bu.)	14.0	12.7	10.6	11.1

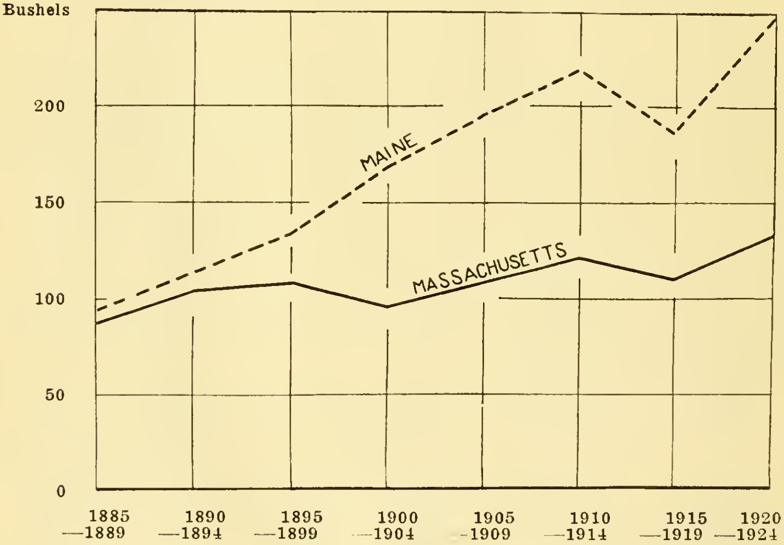
Other Factors Affecting Yield per Acre.

The foregoing discussion of the unit amounts of materials in each area suggests ways in which labor and materials may be conserved. Reasons for many of the variations are given and possible ways of improvement pointed out. The preceding section on costs of special machinery shows the possibilities open in that direction. Reference to different varieties has been made.

Previous studies by many investigators have shown that probably the most important factor in cost per bushel of potatoes is yield per acre. High yields, if secured without undue expenditure for seed, fertilizer, or other factors, mean lower costs per bushel.

Rainfall, temperature, elevation, soil, and other natural factors have all been shown to be associated with yield per acre. But these are all beyond the control of the individual farmer on a particular farm. Of the factors within his control, seed and fertilizer are the most important, a fact established by several investigators. Spraying is also an important factor, affecting yields especially in years when disease is prevalent. The data secured in this study do not lend themselves to a determination of the most profitable rates of seeding and fertilizing because of the variation in soils and previous cropping on the farms studied. However, Hardenburg,[7] after analyzing several hundred potato records from various parts of New York, found that very few growers had exceeded the optimum rate of seeding. Black, Tolley, and Ezekiel[8] with 300 farm records from Monroe County, New York, found the same to be true both with seed and fertilizer.

Figure 11. Average Yield per Acre of Potatoes in Maine and Massachusetts (5 year averages.)



Yields in Maine have increased with improved seed, more adequate disease control, heavier applications of fertilizer, and commercialized practice in general. Yields in Massachusetts have advanced less rapidly.

The high yields in Maine have been obtained only in recent decades. They were formerly as low as in Massachusetts. The changes in yields in Maine and Massachusetts by 5-year periods are shown in Figure 11. The more rapid increase in Maine has been due to several factors. Certified seed, heavier rates of fertilizing, more adequate spraying, the opening up of the Aroostook country, and large commercial potato farms are among the causes. Production in Massachusetts has continued to be on general farms, and supplementary to other enterprises.

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[7] Hardenburg, E. V. A Study, by the Crop Survey Method, of Factors influencing the Yield of Potatoes. New York (Cornell) Agr. Exp. Sta. Memoir 57, 1922.

[8] Tolley, H. R., Black, J. D., and Ezekiel, M. J. B. Input as Related to Output in Farm Organization and Cost of Production Studies. United States Department of Agriculture, Bulletin 1277. 1924.

Application of Input Data to the Individual Farm Business.

It is often desirable to approximate rates for the different items entering into the production of farm crops and work out cost statements. Such statements are useful in comparing the efficiency of different farmers in growing particular crops. For this purpose it is not necessary to have complete cost statements. Minor costs frequently may be omitted. Common labor and land charges may be assumed.

Comparative Cost Statements for Two Chesterfield Growers.

On this basis comparative cost statements for potatoes have been worked out for farms 1 and 10. An arbitrary rate of 40 cents an hour is assigned to man labor, 20 cents to horse work, and $1.25 to tractor work. The land charge is placed at $10.00 per acre. No charge is included for manure. There were 15 tons per acre applied on farm 1 and 18 tons on farm 10. Neither is a charge included for equipment. The other items are cash charges and are placed at the same rate for both farms. Similar machinery is in use on the two farms. The costs per acre of potatoes on these farms in 1926 were then estimated as follows:

TABLE 13.—Comparative Cost Statements. Chesterfield.

Item	Farm 1		Farm 10	
	Rate	Amount	Rate	Amount
Man labor	99 hrs. at $ .40	$ 39.60	130 hrs. at $ .40	$52.00
Horse labor	91 hrs. at .20	18.20	112 hrs. at .20	22.40
Tractor work			2.3 hrs. at 1.25	2.88
Seed	18 bu at 2.50	45.00	13 bu at 2.50	32.50
Fertilizer	1600 lbs. at 50.00	40.00	1000 lbs. at 50.00	25.00
Land	$10 per acre	10.00	$10 per acre	10.00
Spray material—Bordeaux	62 lbs.	3.75	280 lbs.	13.60
lead	4 lbs.		7 lbs.	
Corrosive sublimate	5 oz.	.70	4½ oz.	.65
Total these items per acre		*$157.25*		*$159.03*
Yield per acre	218 bu.		271 bu.	
Cost per bushel[a]		.72		.59

[a] Interest and machine cost not included.

As thus estimated, the cost per bushel on farm 1 in 1926 was 72 cents and on farm 10, 59 cents. The price received for potatoes on these farms in 1926 was $1.50. Both farms had a good margin out of which to take care of overhead and machinery costs and leave a profit.

The total costs per acre were about the same; the chief cause of difference in cost per bushel being differences in yield. These farms are only a few miles apart, at about the same elevation, and have about the same type of soil. The fertility on farm 1 is probably somewhat less than on farm 10. Both men followed the same general cultural methods and the chances are that any reduction in costs would have to come from study made of the factors affecting yield.

A study of these factors shows that on farm 1 half of the potatoes had followed potatoes for several years, while on farm 10 the soil was fall-plowed sod. The manure and fertilizer applications were a little heavier on farm 1. Both men planted their own seed. Farm 10 planted less because No. 2 potatoes were used. More spraying was done on farm 10 and farm 1 had some disease.

Comparative Cost Statements for Two Seekonk Growers.

Comparative cost statements for farms 42 and 53 in the Seekonk area are shown. Rates similar to those in the previous cost statements are used for the non-cash items, except that land is estimated at $20.00. No charge has been included for machinery. This would be higher on farm 42 than on farm 53, for a planter, sprayer, and digger were used; while everything was done by hand on farm 53. (It is estimated that the annual charge for these machines would not have exceeded $10.00 per acre on the 10 acres grown on farm 42.)

Table 14.—Comparative Cost Statements. Seekonk.

Item	Farm 42		Farm 53	
	Rate	Amount	Rate	Amount
Man labor	96 hrs. at $ .40	$ 38.40	167 hrs. at $ .40	$ 66.80
Horse labor	87 hrs. at .20	17.40	104 hrs. at .20	20.80
Seed	10 bu at 4.00	40.00	11 bu. at 4.00	44.00
Fertilizer	2000 lbs. at 40.00	40.00	2000 lbs. at 40.00	40.00
Rye seed	2 bu. at 1.50	3.00		
Spray material (lead)	10 lbs. at .19	1.90	9 lbs. at .19	1.71
Land	$20 per acre	20.00	$20 per acre	20.00
Total these items per acre		*$160.70*		*$193.31*
Yield per acre	192 bu.		145 bu.	
Cost per bushel		.83		1.33

On this basis the cost per acre was higher on farm 53 than on farm 42, due almost altogether to the difference in man labor; and the cost per bushel was still higher because of the lower yield. Careful study of the records of the two farms and a knowledge of the soils indicates that the soil on farm 53 has been more heavily cropped and is in poor physical condition. The grower on farm 42 has paid more attention to rotation and has used rye for a cover crop. Both Green Mountains and Cobblers were raised on farm 53 and the Green Mountains did not do well. They yielded about 133 bushels as compared with about 160 bushels per acre for the Cobblers.

The average farm price for all the potatoes sold on farm 42 was $1.25 and on farm 53, $1.40, the difference being due to the Green Mountains raised on farm 53. Thus the margin between selling price and the costs we have considered was 42 cents on farm 42 and on farm 53 it was 7 cents per bushel.

Other comparisons can easily be made between different farms by applying cost rates to the inputs of labor and materials on those farms. It need hardly be said that the foregoing statements for the cost of potatoes are presented merely as suggestions. They are designed primarily to show one of the methods by which such data can be used. The organization of a farming program, including the management of a particular enterprise, such as the potato crop, is a problem peculiar to each farm.

Costs may not only be calculated for other farms but similarly costs may be approximated for particular operations or groups of operations. Although this method is primarily adapted to making comparisons between individual farms, it is easily possible to draw conclusions of significance to entire groups of farms which are similar to the ones compared.

It is realized that cost statements made in this way do not make a sufficient allowance for other crop or livestock enterprises which may conflict with potatoes in their use of labor or materials. The farmer should try to apportion his own labor, the available labor of other members of the family, and other resources among the various farm enterprises so as to get the largest possible return. If he is definitely limited as to the amount of any of the factors of production, he should try to apportion all the factors so as to get the highest average returns from each unit of the limited factor. This will involve a comparison of the probable alternative returns from the fixed farm resources if used by different enterprises at a particular time, as well as a comparison of the probable returns from varying amounts of labor and materials that can be bought at a particular time.

Thus a change in the method of conducting the potato enterprise may involve a consideration of the effect of the change on other enterprises. However, this is not a serious limitation to the use of these data, provided the point is kept in mind.

Conclusions

1. The competitive position of the individual Massachusetts potato grower is determined by the degree to which he is able and willing to adjust farm practices to meet changes in price determined by forces largely outside Massachusetts.

2. The adjustment can be brought about either by changing fertilizer, seed, or other material inputs to secure varying yields; or by using machinery or different technique to reduce man and horse labor.

3. The variation in the amounts of seed, fertilizer, and other materials used is so great as to make it certain that most farmers can profitably spend much time and thought in working out for their own conditions the best amounts of these materials.

4. The great saving of labor effected by specialized machinery makes its use imperative if the grower would keep his costs as low as his competitors'.

5. The potato crop is a profitable side line in connection with dairying, market gardening, and for many general farms in Massachusetts. Potatoes could probably be grown with profit on many farms which do not now include them as a part of the cropping scheme.

6. In the final analysis, the place of the potato enterprise on any one farm is an individual problem peculiar to that farm. The farmers who make the largest net income are usually those who are most efficient in apportioning their own labor, the available labor of members of their families, and their other fixed resources among all the enterprises of the farm. This may sometimes mean including a crop such as potatoes, even if conditions seem poor; or it may mean excluding potatoes even though costs are apparently low.

5 M 3-'28 No. 1746.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 241 March, 1928

The Food Consumption of Rural School Children in Relation to Their Health

By Esther S. Davies

A field study of two Massachusetts rural towns was made in 1927, to ascertain what relationship, if any, could be demonstrated between the dietary habits of children of elementary school age and their state of health. The investigation included visits to the homes of the children, inspection of school lunches, and dental and medical examinations. The conditions which were found and their relations to the health of the children are described in this bulletin.

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AGRICULTURAL EXPERIMENT STATION
AMHERST, MASS.

THE FOOD CONSUMPTION OF RURAL SCHOOL CHILDREN IN RELATION TO THEIR HEALTH

By Esther S. Davies[1]

In Charge of Home Economics Research

PART I. PURPOSE AND METHOD OF INVESTIGATION

The investigation which is the subject of this report had as its objective the portrayal of the food habits and dietary history of white children in the elementary schools of selected rural Massachusetts towns; the correlation with their food records of their physical status as shown by dental and medical examinations; and the determination, if possible, of the ways in which the prevailing food habits of these children affect their health.

Method of Study

The survey was conducted by means of visits to the homes, questionnaires filled out by the pupils in the schools, examinations of the teeth by a dental hygienist, and medical examinations given by the staff of the children's clinic of the Division of Tuberculosis of the State Department of Health. The medical examinations were made possible through the courtesy and the co-operation of Dr. Henry D. Chadwick, acting director of the Division. Copies of the blanks used in the survey will be found in the Appendix.

Choice of Towns for Field Work

The localities chosen for the field work were selected on the basis of being (1) towns of 1,000 to 1,500 inhabitants, with as large proportions of native white stock as could be found; (2) not in close proximity to any large urban center; (3) places where the superintendent of schools was willing to give the field workers free access to all schools; (4) communities where, for at least two years, the children's clinic had not been held; and (5) towns whose selectmen were willing to request the holding of the clinic.

Through correspondence with the home demonstration agents of the various counties, a list of towns apparently meeting the first three of the above requirements was secured, and through consultation with the chief of the clinic regarding (4) and (5) the choice was narrowed down still further; finally after personal visits to several towns, Carver in Plymouth County and Southwick in Hampden County were selected.

Carver

The town of Carver is west of Plymouth, approximately 10 miles inland from the ocean. Its population, according to the state census of 1925, is 1,306, the principal racial groups being native whites, Finns, French Canadians, and the so-called "black" Portuguese. The town is known for its cranberries and most of the inhabitants gain a fairly comfortable living from the bogs.

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[1] The author wishes to acknowledge the help of Mary S. Rose, Professor of Nutrition, Columbia University, in the determination of scores for evaluating diets, and her kindness in reading and criticizing the manuscript of the report. To Helen Knowlton, of the Department of Rural Home Life, Massachusetts Agricultural College, credit is due for many suggestions regarding the schedules used in the survey of food practices.

Carver is a long, narrow town, with the three settlements of North, Center, and South Carver, each having its schoolhouse, its grocery, and its post office. The smaller places, East and West Carver, are scarcely more than clusters of houses about the crossroads. The old one-room schools have been abandoned and partial consolidation has taken place. North Carver has a three-teacher school for children in the first four grades; South Carver a two-teacher school, also for the first four grades. For the four upper grades there is only one school, with four teachers, located at Center Carver. Bus service is provided to bring the children back and forth to all three school buildings. The town maintains no high school.

Southwick

Southwick lies along the western part of the southern border of the state, in the valley of the Connecticut River. Its population in 1925 was 1,267, with native whites, American negroes, Poles, Swedes, and Italians the predominating nationalities. It is an agricultural town, devoted chiefly to tobacco and dairy farming. The only settlement of any size is Southwick Center, on the main highway five miles from the city of Westfield.

At the time of the survey Southwick was still using the old one-room schools. Scattered throughout the town there were 11 such buildings, every one inadequate and unsuitable. Two rooms on the first floor of the town hall were also used for school rooms. In nine schools anywhere from 5 to 8 grades were being taught by one teacher. In two a beginning at centralization had been made, utilizing the bus service maintained to take pupils to high school in Westfield. One of these schools had only first and second grade pupils; the other, third and fourth grade.

In fairness to Southwick, it should be stated that in the spring of 1927 an appropriation was voted for the purchase of a site and the erection of a modern elementary school building, at Southwick Center, to accommodate all the pupils of the town; and for the establishment of a system of transportation when the building is ready for use. It is hoped that after the school year 1927-28 the old buildings will be no longer needed for school purposes.

The two towns compared

The two towns, Carver and Southwick, have many points in common. Not only are their total populations nearly the same, but also the proportions of native white stock. Both economically and intellectually, few marked differences could be discovered by the investigator. The estimates of general family intelligence and economic status, made at the time of the home visits, are shown in Tables 1 and 2.

Each town has but one resident physician, no dentist, and only one part-time school nurse.

The elementary school enrollment of each of the towns averages 275. Carver has the larger floating element in its school population, as many of the Portuguese move away when the cranberry season ends in the late fall, frequently returning after Easter. At the time of the survey Carver had 70 "black" Portuguese school children but only one American negro; Southwick, 15 of negro blood, most of them living in one section of the town and consequently attending the same school.

Inasmuch as this survey of food habits was limited to white children, the distribution of the American negroes and "black" Portuguese is without significance. Because of the differences in racial habits, physical characteristics,

Table 1. Estimates of Family Intelligence

Intelligence	CARVER						SOUTHWICK						TWO TOWNS					
	Native, mixed		Foreign		**Total**		Native, mixed		Foreign		**Total**		Native, mixed		Foreign		**Total**	
	No.	*Per cent*	No.	*Per cent*	**No.**	*Per cent*	No.	*Per cent*	No.	*Per cent*	**No.**	*Per cent*	No.	*Per cent*	No.	*Per cent*	**No.**	*Per cent*
High	17	*33*	2	*7*	**19**	*24*	22	*43*	3	*24*	**25**	*39*	39	*38*	5	*12*	**44**	*30*
Medium	23	*45*	11	*38*	**34**	*42*	18	*35*	5	*38*	**23**	*36*	41	*40*	16	*38*	**57**	*40*
Low	11	*22*	16	*55*	**27**	*34*	11	*22*	5	*38*	**16**	*25*	22	*22*	21	*50*	**43**	*30*
Total	**51**	*100*	**29**	*100*	**80**	*100*	**51**	*100*	**13**	*100*	**64**	*100*	**102**	*100*	**42**	*100*	**144**	*100*

Table 2. Estimates of Family Income

Income	CARVER						SOUTHWICK						TWO TOWNS					
	Native, mixed		Foreign		**Total**		Native, mixed		Foreign		**Total**		Native, mixed		Foreign		**Total**	
	No.	*Per cent*	No.	*Per cent*	**No.**	*Per cent*	No.	*Per cent*	No.	*Per cent*	**No.**	*Per cent*	No.	*Per cent*	No.	*Per cent*	**No.**	*Per cent*
High	8	*16*	1	*3*	**9**	*11*	19	*38*	2	*15*	**21**	*33*	27	*27*	3	*7*	**30**	*21*
Medium	29	*57*	9	*31*	**38**	*48*	16	*31*	7	*54*	**23**	*36*	45	*44*	16	*38*	**61**	*42*
Low	14	*27*	19	*66*	**33**	*41*	16	*31*	4	*31*	**20**	*31*	30	*29*	23	*55*	**53**	*37*
Total	**51**	*100*	**29**	*100*	**80**	*100*	**51**	*100*	**13**	*100*	**64**	*100*	**102**	*100*	**42**	*100*	**144**	*100*

and immunity or susceptibility to various types of disease common to colored populations, it was felt that the inclusion of data upon colored children with those concerning white children would make the total group too heterogeneous for valid conclusions. No attempt was made to make a separate study of the colored children of either Carver or Southwick because it was not feasible to secure home records.

The principal differences between Carver and Southwick, so far as this study is concerned, lie in their industries and their schools and the effects of these on food habits:—cranberries on the one hand and dairy cows on the other; centralized schools to which most of the pupils travel by bus, and one-room buildings scattered over the countryside so that many of the pupils not only walk to school in the morning and home at night, but also go home for the noon meal.

Number of Records Secured

As may be seen in Table 3, in each of the towns records were obtained from 51 families of native or mixed parentage, the 51 Carver families having 95 children in the elementary schools and the Southwick families 93. In 29 of the Carver families with both parents foreign-born, some one was found who spoke English well enough to give the information desired for the home record; in Southwick, in only 13 families with both parents foreign-born could records be secured. Food histories, therefore, were secured for 60 Carver children and for 27 Southwick children of foreign parentage. The distribution of the children by age and sex is shown in Table 4.

TABLE 3. Children and Families with Home Records

	Carver	Southwick	Total
Families with home records:			
Both parents native-born	42	43	**85**
Mixed parentage	9	8	**17**
Both parents foreign-born	29(a)	13(b)	**42**
Total families	**80**	**64**	**144**
Children with home records:			
Native and mixed parentage	95	93	**188**
Foreign parentage	60	27	**87**
Total children:			
Boys	78	66	**144**
Girls	77	54	**131**
Both sexes	**155**	**120**	**275**

(a) Finnish, 19; French Canadian, 9; Italian, 1.
(b) Polish, 4; Swedish, 4; Italian, 1; Czecho-Slovak, 1; Finnish, 1; Irish, 1; French Canadian, 1.

Dental examinations were made on 168 of Carver's white children, 105 of these being of native or mixed parentage and 63 of foreign; in Southwick, 232 children, 115 of native or mixed and 117 of foreign parentage.

Procedure in the Field

Through the kindness of the superintendents of schools, the official registers were used to obtain the names of the children in each of the elementary grades, sex and age, name of parent or guardian, and home address. Both superin-

Table 4. Children in Family Groups, by Year of Birth and Sex

Year of birth	CARVER			SOUTHWICK			TWO TOWNS		
	Male	Female	**Total**	Male	Female	**Total**	Male	Female	**Total**
1910	0	0	**0**	1	0	**1**	1	0	**1**
1911	2	0	**2**	1	0	**1**	3	0	**3**
1912	2	5	**7**	6	2	**8**	8	7	**15**
1913	11	3	**14**	2	1	**3**	13	4	**17**
1914	8	11	**19**	7	0	**16**	15	20	**35**
1915	15	13	**28**	9	2	**11**	24	15	**39**
1916	5	10	**15**	7	4	**11**	12	14	**26**
1917	10	8	**18**	5	5	**10**	15	13	**28**
1918	12	4	**16**	6	10	**16**	18	14	**32**
1919	6	12	**18**	5	9	**14**	11	21	**32**
1920	7	11	**18**	12	9	**21**	19	20	**39**
1921	0	0	**0**	5	3	8	5	3	8
All ages	**78**	**77**	**155**	**66**	**54**	**120**	**144**	**131**	**275**

tendents took pains to notify all their teachers that the worker was coming and that she was to be given all the assistance from the teacher which she might wish, including plenty of opportunity to talk to the children and a chance to have them fill out the school questionnaire during regular sessions. Had it not been for this interest on the part of the superintendents of schools, the field work would have been far more difficult than it proved to be.

The first step in the field study was to visit every school room and talk with the teachers about the object of the survey, in particular, explaining to them the plans for the clinic sessions and the dental examinations. A short talk was made to the children, and they were urged to be sure to tell their parents that the worker would be at their homes to talk with the mothers. Experience proved that this procedure was of great value, as it gave an excellent introduction to the homes.

About a week sufficed to make all the pupils feel quite well acquainted with the field worker. Then they began, as they walked along the roads to and from school, to call out "Good morning" to her as she drove by—a sign that it was time to begin the home visiting. Practically every parent met her at the door with the words, "Oh, yes, you're the nurse my children said was coming to talk to me about their health."

The school blank was chiefly useful as a means of introducing the idea of the survey to the homes through the children. Otherwise, except for the children's reports on their noon meals, it is felt that the answers of the children were neither adequate nor accurate; not because of unwillingness on the part of the children, but on account of their inability to remember and their actual lack of information. For example, it was only in the three upper grades that the pupils felt any certainty about the distance from home to school, or about the hours of going to bed and getting up. The reports on the noon meals are, on the whole, very reliable; in most instances, if the child had brought his lunch to school the teacher had him get the box and then and there write down a list of its contents; at other times, the worker visited the school immediately upon the opening of the afternoon session and the children reported on the meal eaten within the past hour. The teachers, knowing in advance that this would be done, watched carefully the lunches eaten at the building and helped supply the information, especially about the meals of the younger pupils.

An average of six or seven home visits could be made in one day. The parents were invariably courteous, even if not particularly interested, and it is believed that in no case was there any conscious attempt to deceive as to the truth about the food habits and the dietary history of the children.

For examining the teeth of the school children, a dental hygienist of experience was secured through the dental consultant of the State Department of Health. A description of the methods she used will be found on page 129.

The clinic sessions were in both instances held after the field work in the town had been completed and the writer was not present either time. All arrangements for them were made by the local nurse and a representative of the staff of the Division of Tuberculosis. Except for obtaining the consent to examination in cases where a home visit was made to get food history, the writer was not directly connected with the work of the clinic. The reports of the clinic physicians upon the individual children examined were copied later.

PART II. FOOD HABITS AND DIETARY HISTORY

Limitations of the Data

Although in the home visits an effort was made to secure information upon all the points listed in the blank, experience showed that it was not possible to obtain data of any reliability upon the mother's diet during pregnancy, or the diet of the child during the pre-school years. In general, the mothers remembered the length of time the children had been nursed if breast fed; but the usual answer to questions upon the child's diet after weaning was either "just about the same as he eats now" or "like the rest of the family." In the 144 families surveyed, only 8 mothers were found, 3 in Carver and 5 in Southwick, who had made a practice of straining or mashing vegetables for small children or otherwise preparing their food by methods other than those used for the food of the adults. In the same way, it was the exceptional mother who had tried during pregnancy to eat those foods which might be best for herself or the child; the customary answers as to antepartum diet were "I don't remember anything different" or "I ate anything I wanted."

Upon only one point could anything approaching accurate information be obtained about the amounts of various foods eaten by the children during the pre-school years. This was in relation to the amount of milk consumed. Through questioning as to where the mother had been accustomed to buy milk, the amount generally purchased, or the number of cows the family kept, as well as the mother's recollection of the child's habits in using milk, a reliable estimate of the child's milk consumption could be obtained. The relation between the amount of milk used by the individual children during the pre-school years and that of their present, or school period, diet is shown in Chart 1 for Carver and Chart 2 for Southwick. It will be seen that in both towns there is positive correlation between the amounts of milk utilized during the two periods.

It has been considered unjustifiable to employ any of the more refined statistical methods in the handling of the material of this study, the inherent inaccuracies of the original data not warranting such procedure. The diet scores themselves and, as a result, the comparisons with conditions of teeth, weight, and other elements in health status are all necessarily based upon information which was dependent for its correctness upon the memories of the mothers, resulting in many chances of error in individual cases. For this reason no such statistical computations have been made, and a simpler mode

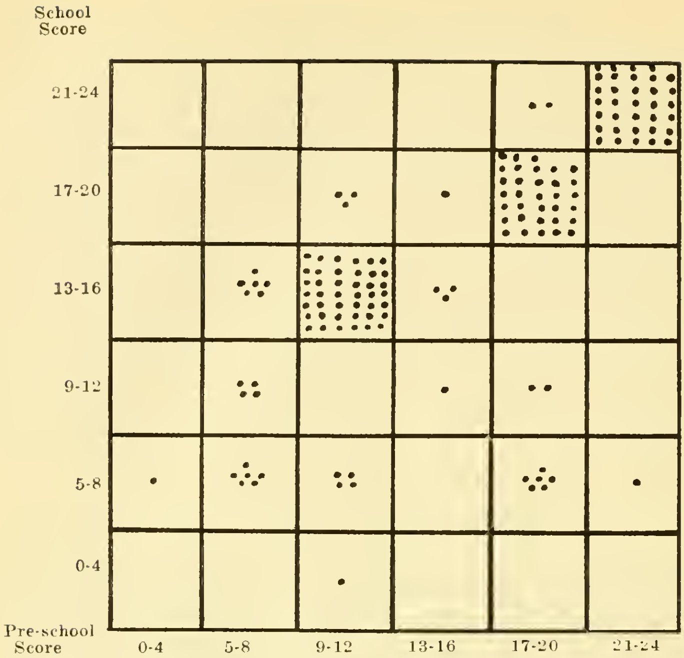


CHART 1. The Relationship between the Milk Scores of 155 CARVER Children for Pre-school Years and for the School Period.

Each dot represents the milk consumption of one child, scored on the basis of 24 for one quart a day and smaller amounts in direct proportion.

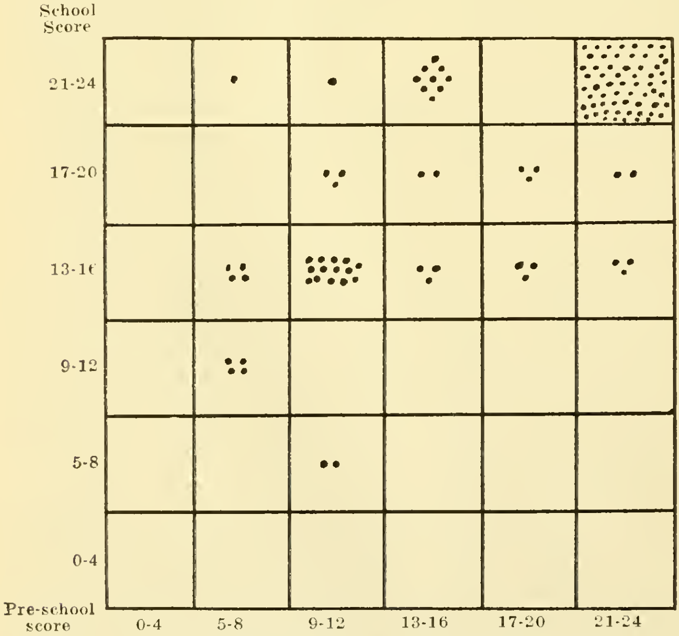


CHART 2. The Relationship between the Milk Scores of 116 SOUTHWICK Children for Pre-school Years and for the School Period.

Each dot represents the milk consumption of one child, scored on the basis of 24 for one quart a day and smaller amounts in direct proportion of presentation has been adopted, in order that the refinements of method may not exceed the refinements of accuracy in the foundation data.

On the other hand, the numbers included in the study are sufficient to make certain trends stand out clearly. The general or customary practices of the two groups of children, from Carver and Southwick, become quite apparent and, so far as health status could be evaluated, there is a well-defined relation between the food habits and the health of the groups.

The treatment of the material relating to food habits is necessarily qualitative. With the single exception of milk, it was futile to attempt, in a survey of this sort, the collection of quantitative data. For example, most of the mothers interviewed knew very well how often they usually had meat during the week; but had no idea of how much each child ate. The same thing is true of the other foods. Milk is the only one about which these women were accustomed to thinking in terms of quantity.

However, it is believed, from personal observation of meals, that, in general, the sizes of servings of different articles of the diet, such as potatoes, other cooked vegetables, bread and cereals, and pieces of pie or cake, did not vary much from family to family; and that the frequency with which a given food appeared on the family menu may be considered a rough indication of the amounts eaten by individual children. It is upon this basis that scores have been used to compare the food habits of one child with those of another.

The Optimum Score

For the diet during the school period, i. e., from six years of age upwards, the following numerical allowances were allotted to the types of food indicated:

Food	Standard	Optimum score
Milk	1 qt. a day	24
Vegetables		
potato	once a day	5
other than potato or leafy	once a day	10
leafy	four times a week	8
Fruit		
cooked	once a day	7
raw (or raw vegetable or canned tomato)	twice a day	14
Bread and cereals		
whole grain	twice a day	14
{Eggs	three times a week	9
{Meat	once a day	9
		100
Coffee or tea		deduct 10

Any such method of scoring should take into account both qualitative and quantitative factors. Since milk is both qualitatively and quantitatively important, it should have the highest score, and since it should furnish approximately 25 per cent of the total calories, the major portion of the calcium, and more than 50 per cent of the phosphorus, a large number of units of vitamines A and B, and a considerable amount of iron, which is utilized very efficiently in nutrition, a score of 24 seems very moderate.

Since, next to milk, the most important item in guaranteeing a well-balanced diet is a liberal supply of vegetables, they should have a score nearly as high as milk (in this case 23 per cent). Vegetables are best subdivided into groups, setting the leafy vegetables in one and the potato in another. Leafy vegetables are high in ash and vitamines and low in calories; and other vegetables, if used in variety, to some extent will take their place and add to their calories, so that the scores for these two groups should not be very different. The potato should not be used to the exclusion of other vegetables, but it should be used with considerable freedom on account of its ash and vitamines and especially iron and vitamine C. Because the potato is only one member of the vegetable group, it should not have quite so high a score as the other two.

Fruits, like vegetables, contribute to the ash and vitamine value of the diet and are even more important in furnishing vitamine C, so that a score of 21 for them (which is only slightly lower than for the vegetables) seems desirable, giving higher value to the raw fruit.

With the liberal supply of milk, eggs and meat (which supplement milk especially for protein and calories) may together have a somewhat lower score (18). Since the egg is more of a factor in growth than meat, it deserves a score as high as meat even when used only three times a week.

Although any scoring system has the fault of arbitrariness, some measure had to be devised to compare one diet with another. It is believed that the division of the score into five recognized food divisions has not only greatly facilitated the work of evaluating diets of different character, but has resulted in total scores which, when contrasted one with another, represent, as far as is possible in terms of numbers, the dietary values of the food habits of the children studied.

Scores for Diets as a Whole

Using the numerical allowances of this scheme of scoring, the diets of 155 Carver and 120 Southwick children during their school years were graded, and the distributions of the resulting scores are presented in Tables 5 and 6. Everywhere in this report the records of the children of mixed parentage are, for both towns, combined with those for the children of native parentage; partly because the numbers of children of mixed parentage are too small for separate consideration, but principally because the visits to the homes showed that the habits of these families of mixed parentage are practically the same as those of the native families.

Forty-five per cent of the diets of the 95 Carver children of native and mixed parentage have scores ranging from 40 to 60 on a scale of 100; while for the 93 Southwick children of native and mixed parentage the largest group, 48 per cent, is found higher on the scale, between the scores of 60 and 80.

Because of the smallness of the total number of children of foreign parentage, percentages have not been computed for the distributions of the diet

Table 5. Scores of Present Diets of 155 Carver Children of Elementary School Age, by Nationality

Score	Native and mixed		Finnish	All foreign		**Total all children**	
	No.	*Per cent*	No.	No.	*Per cent*	**No.**	*Per cent*
20—24	1	*1*	1	1	*2*	**2**	*1*
25—29	1	*1*	2	2	*3*	**3**	*2*
30—34	1	*1*	0	2	*3*	**3**	*2*
35—39	8	*8*	1	5	*8*	**13**	*8*
40—44	6	*6*	8	10	*17*	**16**	*11*
45—49	14	*15*	3	3	*5*	**17**	*12*
50—54	13	*14*	13	16	*26*	**29**	*18*
55—59	9	*10*	11	13	*22*	**22**	*14*
60—64	9	*10*	6	6	*10*	**15**	*9*
65—69	11	*11*	1	1	*2*	**12**	*8*
70—74	7	*7*	0	0	*0*	**7**	*5*
75—79	3	*3*	0	1	*2*	**4**	*3*
80—84	9	*10*	0	0	*0*	**9**	*5*
85—89	3	*3*	0	0	*0*	**3**	*2*
90—94	0	*0*	0	0	*0*	**0**	*0*
95—100	0	*0*	0	0	*0*	**0**	*0*
Total	**95**	*100*	**46**	**60**	*100*	**155**	*100*

Table 6. Scores of Present Diets of 120 Southwick Children of Elementary School Age, by Nationality

Score	Native and mixed		Polish	All foreign		**Total all children**	
	No.	*Per cent*	No.	No.	*Per cent*	**No.**	*Per cent*
20—24	0	*0*	0	0	*0*	**0**	*0*
25—29	0	*0*	0	1	*4*	**1**	*
30—34	7	*8*	0	0	*0*	**7**	*6*
35—39	0	*0*	4	4	*15*	**4**	*3*
40—44	3	*3*	3	3	*11*	**6**	*5*
45—49	11	*12*	0	0	*0*	**11**	*9*
50—54	7	*8*	2	4	*15*	**11**	*9*
55—59	11	*12*	0	3	*11*	**14**	*12*
60—64	19	*20*	0	2	*7*	**21**	*18*
65—69	11	*12*	0	4	*15*	**15**	*13*
70—74	11	*12*	4	5	*18*	**16**	*13*
75—79	4	*4*	0	0	*0*	**4**	*3*
80—84	6	*6*	0	1	*4*	**7**	*6*
85—89	2	*2*	0	0	*0*	**2**	*2*
90—94	1	*1*	0	0	*0*	**1**	*
95—100	0	*0*	0	0	*0*	**0**	*0*
Total	**93**	*100*	**13**	**27**	*100*	**120**	*100*

*Less than one per cent.

scores for the Carver Finnish children or the Southwick Polish children, and these are the only foreign groups large enough to be considered separately at all.

In the diets for all Carver children of foreign parentage, 48 per cent were scored between 50 and 60; only 26 per cent of the scores of the Southwick children of foreign parentage, however, fall here. The distribution of the scores of the diets of these children of foreign parents from Southwick is much more scattering than that of Carver, as there is no one nationality in

Southwick so well represented as the Finns in Carver, resulting in a much more heterogeneous foreign group in Southwick. Moreover, there were 60 Carver children of foreign parentage for whom diet scores were obtained and only 27 in Southwick. The diet scores of these children in the two towns, therefore, are not as comparable as the two native groups.

Charts 3 and 4 show graphically the distributions of the diet scores for Carver and Southwick, for children of native and mixed parentage, those of foreign parentage, and for the total of all children.

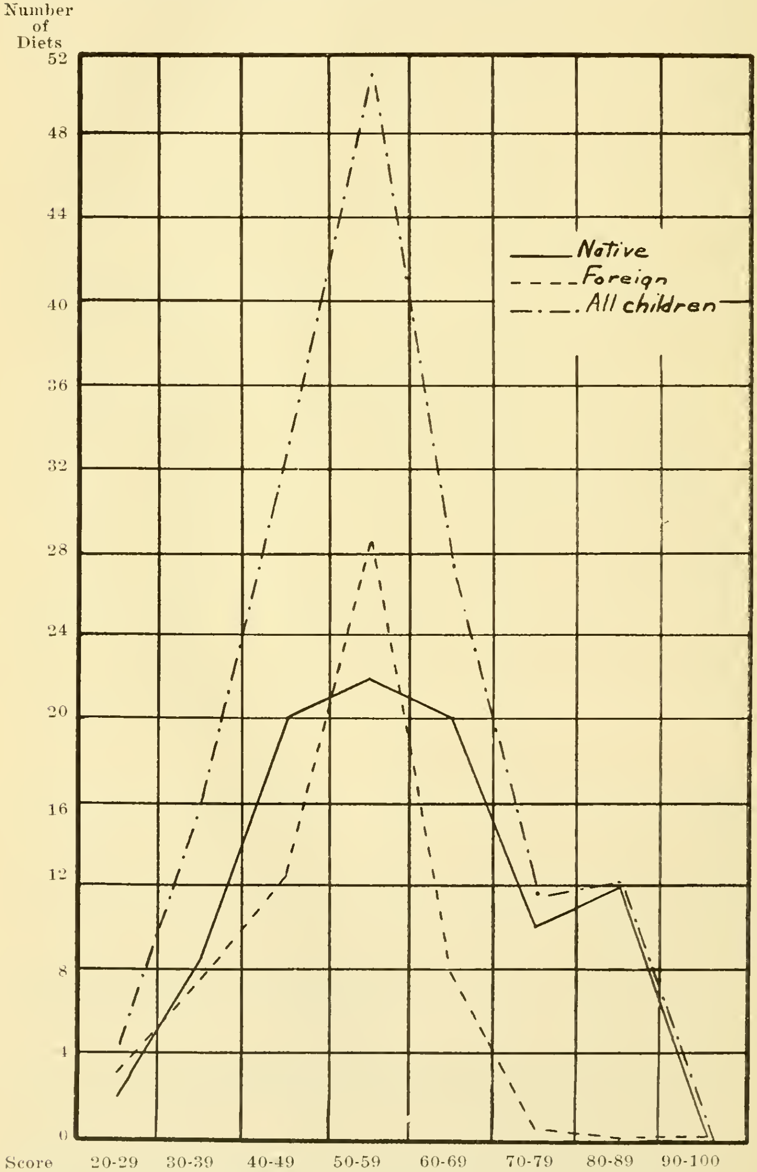


CHART 3. The Distribution of the CARVER Diet Scores for the School Period, for 95 Children of Native and Mixed Parentage and 60 Children of Foreign-born Parents.

Diet score and age of child

No relationship has been discovered between total diet score and age of the child. The various scores are scattered at random among the different ages.

Diet score and family intelligence

The comparison of diet scores with estimates of family intelligence indi-

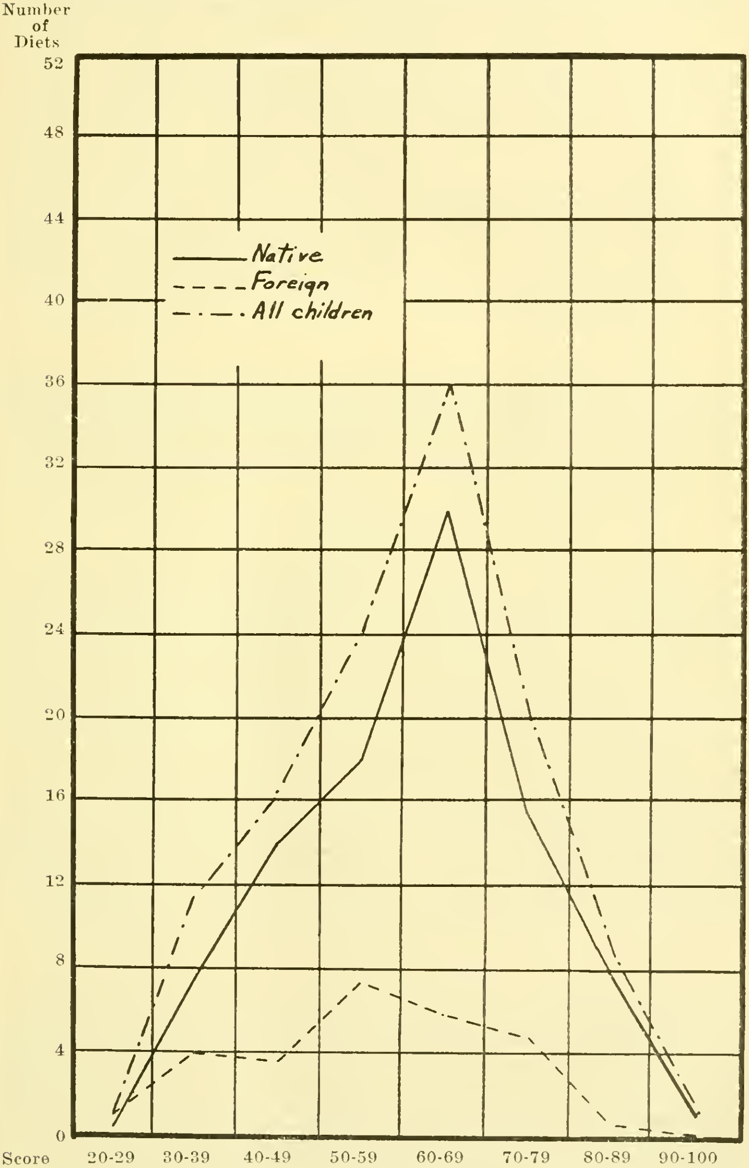


CHART 4. The Distribution of the SOUTHWICK Diet Scores for the School Period, for 93 Children of Native and Mixed Parentage and 27 Children of Foreign-born Parents.

cates a relationship between diet score and intelligence. In Carver, 65 per cent of the diets of children in families judged of high intelligence were scored between 60 and 90; 62 per cent of those of the children in families of medium intelligence, between 30 and 60; in the diets representative of homes of low intelligence, 83 per cent between 30 and 60.

In Southwick, also, the diet scores of most of the children from families of high intelligence are relatively high, 72 per cent being scored between 60 and 90. The diets of the Southwick children from families of medium intelligence, however, do not drop in their scores as those of Carver, 61 per cent being scored from 60 to 90 and 39 per cent from 30 to 60, contrasted with 35 per cent in Carver having scores from 60 to 90 and 62 per cent between 30 and 60. The explanation of this difference is to be found in the more universal use of large quantities of milk in Southwick and the consequent increase in the total diet scores.

In Southwick as in Carver, the same downward trend appears in the diets of children from families of low intelligence, with 70 per cent of these diets scored between 30 and 60.

Diet score and family income

The relationship between the child's diet score and the family's apparent income is in both towns almost exactly the same as that between diet score and family intelligence. The children from families of high income tend to have high diet scores; those of lower income, lower scores.

Milk Supply

As was stated earlier in this report, Southwick has dairying as one of its chief industries, and many large herds are owned by the parents of the school children. Carver, on the other hand, has no large dairy interests. Of the Carver households reported as owning a cow, almost none possessed more than one animal and that was frequently of poor enough stock to be dry four or five months of the year. In spite of the fact that 34 per cent of the native families of Carver were reported as owning a cow, the frequent statement of the mother that the "cow's been dry a long time and I can't buy any fresh milk" bore testimony to the difficulty of obtaining regularly an amount of milk adequate for the family's needs. Fifty-three per cent of the native families of Southwick owned cows and the presence in the town of fine dairy herds made it possible to get very easily milk of good quality. "We have more milk than we can use" was a comment often heard in Southwick.

The Milk Scores

The great difference between the amount of milk consumed by the children of Carver and that used by the Southwick children shows clearly in Table 7 and Chart 5. Of all the Carver children, only 16 per cent had approximately one quart of milk daily, as compared with 64 per cent of all the Southwick children. Among the children of native and mixed parentage, 16 per cent in Carver and 67 per cent in Southwick were reported as using that amount of milk daily; while of the children of foreign parentage 12 per cent in Carver and 56 per cent in Southwick had that much. Inasmuch as the two groups of

TABLE 7. Distribution of Milk Scores

Score*	CARVER						SOUTHWICK					
	Native and mixed		Foreign		Total		Native and mixed		Foreign		Total	
	No.	*Per cent*	No.	*Per cent*	No.	*Per cent*	No.	*Per cent*	No.	*Per cent*	No.	*Per cent*
0–4	1	*1*	0	*0*	**1**	†	0	*0*	0	*0*	**0**	*0*
5–8	14	*15*	4	*7*	**18**	*12*	2	*2*	0	*0*	**2**	*2*
9–12	2	*2*	5	*8*	**7**	*4*	3	*3*	1	*4*	**4**	*3*
13–16	45	*47*	34	*56*	**79**	*51*	18	*19*	9	*33*	**27**	*23*
17–20	18	*19*	7	*12*	**25**	*16*	8	*9*	2	*7*	**10**	*8*
21–24	15	*16*	10	*12*	**25**	*16*	62	*67*	15	*56*	**77**	*64*
Total	**95**	*100*	**60**	*100*	**155**	*100*	**93**	*100*	**27**	*100*	**120**	*100*

*Scored on the basis of 24 for one quart a day, smaller quantities in direct proportion.
†Less than one per cent.

native children are the same size (95 from Carver and 93 from Southwick) and since they come from families of approximately equal intelligence and income, the difference in the amounts of milk used by the children is of much interest and importance. As will be seen later, a very significant relation appears between the amount of milk used and the condition of the teeth.

Vegetable Scores

The vegetable scores, given in Table 8 for both towns and shown again in Chart 5, have been computed on the assumption that an optimal daily consumption of vegetables should include potatoes once a day, leafy vegetables at least four times a week, and another vegetable (i. e., not potato or leafy) once a day. Every child for whom a record was secured was reported to

TABLE 8. Distribution of Vegetable Scores

Score*	CARVER						SOUTHWICK					
	Native and mixed		Foreign		Total		Native and mixed		Foreign		Total	
	No.	*Per cent*	No.	*Per cent*	No.	*Per cent*	No.	*Per cent*	No.	*Per cent*	No.	*Per cent*
0–5	0	*0*	0	*0*	**0**	*0*	0	*0*	0	*0*	**0**	*0*
6–10	15	*16*	25	*42*	**40**	*26*	41	*44*	5	*19*	**46**	*39*
11–15	31	*33*	14	*23*	**45**	*29*	28	*30*	12	*44*	**40**	*33*
16–19	24	*25*	17	*28*	**41**	*26*	22	*24*	6	*22*	**28**	*23*
20–23	25	*26*	4	*7*	**29**	*19*	2	*2*	4	*15*	**6**	*5*
Total	**95**	*100*	**60**	*100*	**155**	*100*	**93**	*100*	**27**	*100*	**120**	*100*

*Scored on the basis of a maximum of 23 points for potatoes once a day, leafy vegetables four times a week and another vegetable once a day; smaller amounts in direct proportion.

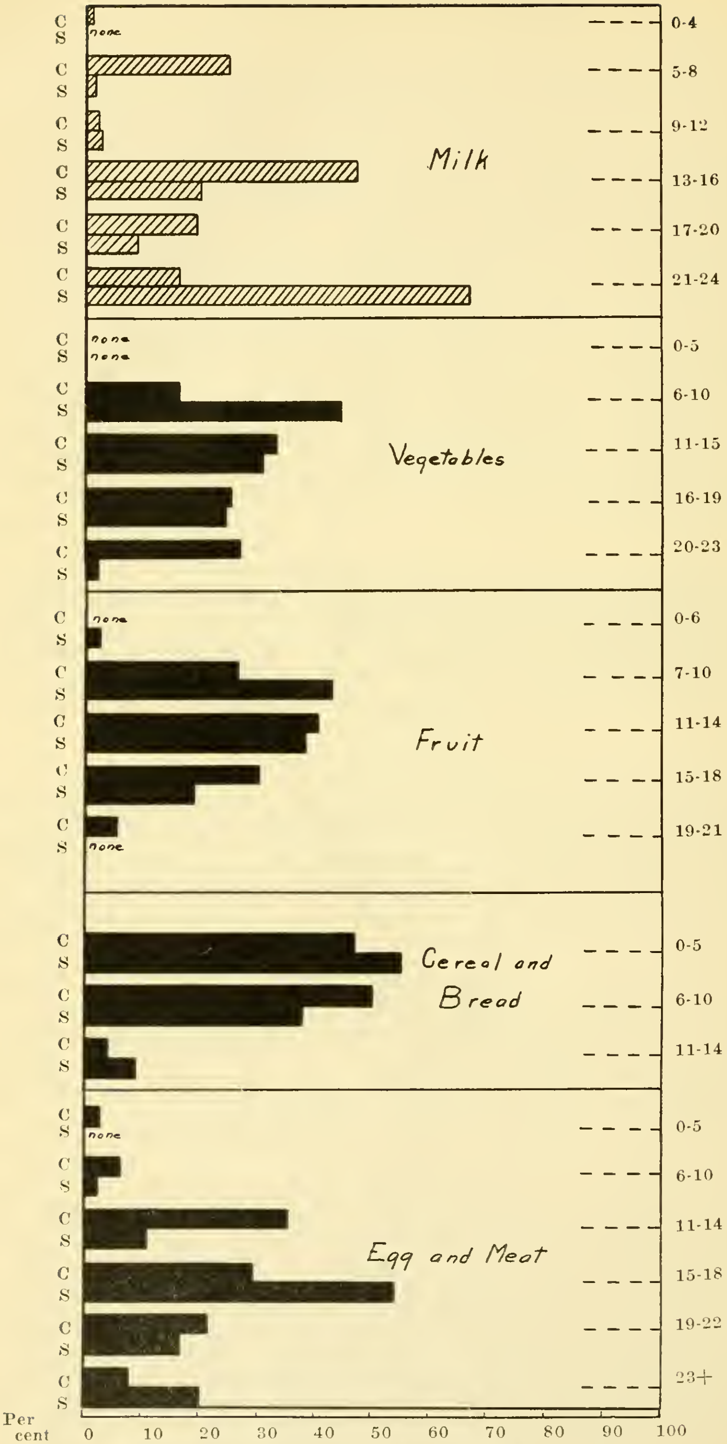


CHART 5. The Distribution of the Scores for the Various Classes of Food, in the Diets of 95 CARVER and 93 SOUTHWICK Children of Native and Mixed Parentage.

have potatoes at least once a day. There are, consequently, no diets in which the vegetable score is less than 5, which is the allowance for potatoes once a day.

The Carver diets scored higher in vegetables than those of Southwick. No conclusive reason for this has been found and the difference cannot be explained with any certainty. Whether the greater use of eggs in Southwick led to less use of vegetables, or whether the difference is owing to the conditions of sampling is not entirely clear. It would not seem that between March (when the Carver records were taken) and May (when the field work was done in Southwick) there would be enough difference in the supply of vegetables to affect the replies of the mothers as to the usual amounts eaten by the children. It is recognized that inevitably many of the mothers had a tendency to report the practice current at the time of the visit as the usual practice, irrespective of season.

One factor in the difference in the vegetable scores of the two towns may perhaps be found in the difference between the groceries of Carver and Southwick. Carver was particularly fortunate in having a most excellent grocery. Personal inspection by the investigator was made of all the groceries in each town, and Southwick had none to compare, so far as stock carried is concerned, with this one. During March, its manager had always on hand a good assortment of raw vegetables, including spinach, and also a large supply of canned goods,—all for sale at reasonable prices. This grocery undoubtedly has an influence upon the dietary habits of the families who do their buying there.

The difference between the use of vegetables in the two towns is not, however, as great as that between the milk utilization. With 23 the optimal vegetable score, one of 16 or over may be taken as representing a fair amount of vegetables in the diet. In Carver, 51 per cent of the children of native parentage had vegetable scores of 16 or over, against only 26 per cent in the native group of Southwick. Among children of foreign-born parentage, 35 per cent in Carver and 37 per cent in Southwick had vegetable scores of 16 or more. And, taking all children together, 45 per cent in Carver and 28 per cent in Southwick had fair amounts of vegetables in the diet. The difference between the two towns is greater when we consider only the children with excellent scores for vegetables; i. e., 20 plus. Here we find 26 per cent of the Carver children of native parentage; only 2 per cent of those in Southwick. And, for all children, the percentages having excellent vegetable scores are 19 for Carver and 5 for Southwick. Why such large differences should exist is not apparent.

The Fruit Scores

Here, too, as in the case of vegetables, Carver diets score higher than those of Southwick. This difference, though, can be explained without difficulty, for a careful scrutiny of the original records reveals the fact that in almost every instance the higher fruit scores of Carver are due to the use of many cranberries.

The two raw fruits eaten most freely in both Carver and Southwick are apples and oranges. Surprisingly few bananas were reported. Apples, in both towns, are plentiful and cheap. Oranges are willingly purchased by many housewives at prices which make them an expensive item on the menu.

Aside from the cranberries of Carver, very little cooked fruit or sauce was used in the families studied. Only two of the 144 housewives from whom records were secured mentioned apple sauce as an article on the family menu. Instead of the easily made apple sauce, these families had apple pie, regardless of the labor involved or the greater tax on digestion.

On the whole, the fruit scores of the children of both towns are good. (See Table 9 and Chart 5.) No child was found who did not have fruit of some kind at least four or five times a week, and most children had raw fruit ten or more times each week,—apples in greatest quantity, oranges next. It seems justifiable to conclude that, in general, these children of Carver and Southwick are getting fair amounts of fruit.

Table 9. Distribution of Fruit Scores

Score*	CARVER						SOUTHWICK					
	Native and mixed		Foreign		**Total**		Native and mixed		Foreign		**Total**	
	No.	*Per cent*	No.	*Per cent*	No.	*Per cent*	No.	*Per cent*	No.	*Per cent*	No.	*Per cent*
0–6	0	*0*	13	*21*	**13**	*8*	2	*2*	3	*11*	**5**	*4*
7–10	25	*26*	9	*15*	**34**	*22*	40	*43*	7	*26*	**47**	*39*
11–14	38	*40*	25	*42*	**63**	*41*	34	*37*	13	*48*	**47**	*39*
15–18	28	*30*	12	*20*	**40**	*26*	17	*18*	4	*15*	**21**	*18*
19–21	4	*4*	1	*2*	**5**	*3*	0	*0*	0	*0*	**0**	*0*
Total	**95**	*100*	**60**	*100*	**155**	*100*	**93**	*100*	**27**	*100*	**120**	*100*

*Scored on the basis of 21 for raw fruit (or raw vegetable or canned tomato) twice a day and cooked fruit once a day; smaller amounts in direct proportion.

Bread and Cereal Scores

For the purposes of this study, the scores for bread and cereal foods have been computed solely on the amounts of whole grain breads and cereals eaten. Without doubt, every child in the families surveyed had an ample supply of refined cereals, particularly white bread. It is not believed that any child failed to get a liberal number of calories. The diets are adequate for fuel needs and it is on the other essentials for nutrition that emphasis should be placed. Since, in evaluating the diets, stress has been laid upon their content of protein, minerals and vitamines rather than on total calories, the data have been computed upon the basis of the frequency with which whole grain foods appeared in the children's menus.

A score of 14 means that the diet contained either whole grain bread or whole grain cereal at least twice daily. By reference to Table 10 and Chart 5, it will be seen that very few of the children in either town have excellent scores for the cereal foods; that the Carver children of foreign parentage score a little higher than those of native parentage; but that in Southwick the children of foreign parentage have lower scores than those of native parentage. These differences come because of the large proportion of Finns in the Carver foreign group, as almost all the Finnish families use a great deal of hard, whole grain bread. To some extent, the native families of Carver have copied this habit of the Finns and for that reason all the scores for whole grain cereal foods are slightly higher in Carver than in Southwick. Nevertheless, in both towns the scores for whole grain cereal foods are so low it seems evident that the children are not getting adequate amounts.

TABLE 10. Distribution of Scores for Whole Grain Cereal Foods

Score*	CARVER						SOUTHWICK					
	Native and mixed		Foreign		Total		Native and mixed		Foreign		Total	
	No.	*Per cent*	No.	*Per cent*	No.	*Per cent*	No.	*Per cent*	No.	*Per cent*	No.	*Per cent*
0–5	45	*47*	24	*40*	**69**	*44*	52	*55*	22	*81*	**74**	*62*
6–10	47	*50*	27	*45*	**74**	*48*	34	*37*	1	*4*	**35**	*29*
11–14	3	*3*	9	*15*	**12**	*8*	7	*8*	4	*15*	**11**	*9*
Total	**95**	*100*	**60**	*100*	**155**	*100*	**93**	*100*	**27**	*100*	**120**	*100*

*Scored on the basis of 14 points for whole grain foods (bread or cereal) twice a day; smaller amounts in direct proportion.

Egg and Meat Scores

In scoring the amount of eggs and meat in each diet, the amount of milk in that diet was taken into consideration, in order that too much or too little allowance be not given to protein-rich foods. For example, if a child had a full quart of milk daily and also meat once a day, 9 points was the maximum allowed for eggs, even if eggs were reported for more than three times a week. On the other hand, if the child had only one pint of milk a day and meat once a day, 3 points were allowed for each egg in the diet up to seven a week. Nothing was allowed for meat more than once a day, and for an excessive amount of meat there was a deduction, varying from 1 to 5 points according to the frequency of meat in excess of once a day.

The possible score for eggs and meat together, therefore, runs up to a maximum of 30 for a diet containing one egg a day and meat once a day, provided the milk of that diet did not exceed one pint a day.

Even with this broad interpretation and the liberal allowances for eggs and meat, the scores given in Table 11 and shown in Chart 5 are not high for either town. Very few deductions were made for meat more than once a day. In Carver, among the 51 native families, only 5 families (including 10 children) reported meat more than once a day; and but 3 foreign families, with 9 children, used meat more than once daily. In Southwick, no foreign family and only one native family (2 children) had in the diet scores any deduction for meat in excess of once a day. The scores of Table 11, therefore, in almost all cases represent the frequency with which meat and eggs appear in the diet.

The egg and meat scores of the Southwick diets are higher than those of Carver. This is chiefly on account of the greater number of eggs reported in Southwick. It is believed that the difference is in large measure caused by the time of year of taking the records. Most of the Carver families were visited in March; the Southwick families in May. Owing to the natural tendency on the part of the housewives to report what was true at the time of the interview rather than an estimate of the usual or most common prac-

Table 11. Distribution of Combined Scores for Eggs and Meat

Score*	CARVER						SOUTHWICK					
	Native and mixed		Foreign		Total		Native and mixed		Foreign		Total	
	No.	*Per cent*	No.	*Per cent*	No.	*Per cent*	No.	*Per cent*	No.	*Per cent*	No.	*Per cent*
0–5	2	*2*	2	*3*	**4**	*3*	0	*0*	0	*0*	**0**	*0*
6–10	5	*5*	5	*8*	**10**	*6*	1	*1*	3	*11*	**4**	*3*
11–14	33	*35*	17	*28*	**50**	*32*	9	*10*	6	*22*	**15**	*12*
15–18	29	*30*	16	*27*	**45**	*29*	49	*53*	11	*41*	**60**	*50*
19–22	20	*21*	10	*17*	**30**	*20*	15	*16*	6	*22*	**21**	*18*
23†	6	*7*	10	*17*	**16**	*10*	19	*20*	1	*4*	**20**	*17*
Total	**95**	*100*	**60**	*100*	**155**	*100*	**93**	*100*	**27**	*100*	**120**	*100*

*Scored on the basis of 9 points for meat once a day, and 9 points for eggs three times a week in diets containing one quart of milk a day. In diets having smaller quantities of milk a proportionally larger allowance was made for eggs, up to a maximum of 21 for one egg a day in diets containing only one pint or less milk daily.

tice of the family, it seems reasonable to conclude that the number of eggs used in Southwick appears high because of the seasonal variation in production. Most of the eggs used by the families in both towns are produced locally, so that time of year has much influence on egg supply.

The amounts of meat in the diets are affected by the facilities for purchase. Many of the housewives of Carver buy meat from a travelling butcher. The wagon comes around two or three times a week and on the other days there is no convenient place where meat can be bought. Meat is available at shops in Southwick Center, but not in those elsewhere in the town. The lack of conveniently located meat markets is thus a factor in keeping down the amount of meat consumed. Meat products are not ordinarily eaten to excess in either town.

Coffee and Tea

In scoring the diets a deduction of 10 points from the total was made for the regular use of either coffee or tea. In Carver 69 children, ranging in age from 6 to 16, drank coffee or tea regularly. Tea is not a common drink and only a few of the older children liked it; hereafter, therefore, discussion will be limited to the use of coffee.

Among the Finns and the French Canadians, coffee is almost universal as the breakfast beverage of all the family past early infancy; 39 of the 69 Carver children who used coffee regularly were Finnish and 11 French Canadian. Of the 95 native children in Carver, only 19 drank coffee and most of them were at least twelve years old. In Southwick there were 25 of the 93 children of native stock who drank coffee; one-third (9 out of 27) of the children of foreign-born parentage used it. No correlation between the drinking of coffee and the state of health could be discovered. In view of the small numbers involved, this is neither surprising nor significant.

Comparison of Scores of Different Foods

Tabulations were made to ascertain what relationship, if any, exists between the scores for milk and those for vegetables, for milk and fruit, and for vegetables and fruit. It seems evident that neither in the diets of Carver nor in those of Southwick is there any tendency for high milk scores to be associated with high or low vegetable or fruit scores; and that fruit scores bear no apparent relation to vegetable scores.

The fruit scores of Carver and Southwick diets were compared with the corresponding total diet scores. No relationship could be discovered, in spite of the fact that the maximum allowance for fruit is 21 per cent of the optimum total score. In the case of vegetable scores and total diet scores, there was a slight positive relationship. When the vegetable score is high, the score for the diet as a whole tends to be high also; and when vegetables are low the total score is apt to be low. The difference between the relation of fruit scores to total scores and that of vegetable scores to total scores is not because of difference in the allowances made for fruit and vegetables, since the maximum for vegetables, 23, is only two points higher than that for fruit. Whether or not a real distinction exists between the two relationships cannot be determined from the data secured in Carver and Southwick.

Between milk scores and total scores there was a moderate degree of positive relationship. The maximum allowance for milk, it will be recalled, is 24, so that the possible effect of the milk score on total score is not much greater than that of the vegetable score, with its maximum at 23. It seems evident from the data at hand that when the supply of either milk or vegetables is adequate the diet as a whole tends also to be adequate.

Adequacy of the Diets

Because of the almost identical size of the two groups of white children of native and mixed parentage—95 in Carver and 93 in Southwick—and because of the fact that they come from families of the same general economic and intellectual level, certain comparisons between the diets of the groups are of interest. The tabulation below recapitulates for each town the information regarding the proportions of these children of native and mixed parentage who may be considered to have in their diets approximately adequate even if not ideal amounts of the various types of food.

Food	Amount	Equivalent score	Children of native and mixed parentage; per cent with designated scores	
			CARVER	SOUTHWICK
Milk	3½ c.+ a day	20+	16	67
Vegetables	potato and 1 other each day	15+	51	26
Fruit	twice a day	14+	34	18
Whole grain cereals or bread	10 times a week	10+	3	8
Eggs or meat	9 times a week	14+	58	89

From this it will be seen that but 16 per cent of the Carver children of native and mixed parentage had a quart or nearly a quart of milk daily, while 67 per cent of those of Southwick had that much; that 51 per cent of the Carver children and 26 per cent of those in Southwick had at least potatoes and one other vegetable daily; 34 per cent of Carver children and 18 per cent of Southwick's generally had fruit of some sort, cooked or raw, twice a day; 3 per cent of Carver's children and 8 per cent of Southwick's ate whole grain cereal or bread at least ten times during the week; and, finally, that 58 per cent of the Carver children and 89 per cent of those in Southwick had meat or eggs a minimum of nine times every week.

A similar table has not been prepared for the total of all children, as the two groups of children with foreign-born parents are not at all similar in racial composition. That of Carver is preponderantly Finnish, while that of Southwick is quite heterogeneous. These groups are not, therefore, sufficiently comparable to warrant the drawing of conclusions regarding dietary differences.

Menus

To get still another picture of the food habits of the children, at every home visit the investigator inquired what the family menus were, either for the day of the interview or for the previous day. There was no apparent hesitation on the part of the women in telling what items had been served at the meals. In addition to the list of foods appearing on the family table, information was sought as to whether the children shared the food of the adults or special provision was made for their needs. Almost no homes were found where any attempt was made to provide food particularly suited to growing boys and girls. In general, the menus were selected on the basis of the likes and the dislikes of the parents, and the children were given free choice of all dishes upon the family table.

In order that the menus collected should be representative of the usual week-day practice, no questions were asked about meals served on Saturdays and Sundays, when the family cooking is apt to be somewhat more elaborate than during the rest of the week.

The main items appearing on the menus for breakfasts, the noon meals eaten at home, the lunches at school, and the evening meals are given for all children in Tables 12, 13, 14, and 15; and also shown for the children of native and mixed parentage in Charts 6, 7, 8, and 9.

Breakfasts

The composite picture of 167 Carver and 165 Southwick breakfasts shows that some form of cereal and either milk or cocoa were the two foods most frequently eaten by the children of native stock in both towns; a little over one-third usually had eggs for breakfast, but less than one-third ordinarily had fruit; 23 per cent of these Carver children and 15 per cent of those in Southwick had coffee or tea (usually coffee). Cake, cookies, or doughnuts—most frequently doughnuts—appeared on the breakfast menus of 17 per cent of the Carver children of native stock; 19 per cent in Southwick.

The breakfasts of the children of foreign-born parentage have been tabulated and the results appear in Table 12.

TABLE 12. Principal Items in Breakfast

Food	CARVER				SOUTHWICK			
	Native		Foreign		Native		Foreign	
	No.	*Per cent*	No.	*Per cent*	No.	*Per cent*	No.	*Per cent*
Raw fruit	31	*30*	10	*16*	35	*28*	0	*0*
No fruit	69	*66*	52	*83*	83	*66*	37	*95*
Cooked cereal	58	*56*	22	*35*	51	*40*	7	*18*
Dry cereal	20	*19*	1	*2*	34	*27*	1	*3*
No cereal	23	*22*	39	*62*	40	*32*	29	*78*
Egg	46	*44*	28	*44*	45	*36*	17	*44*
Milk or cocoa	63	*61*	25	*40*	99	*79*	25	*64*
Coffee or tea	24	*23*	40	*63*	19	*15*	10	*26*
Cake, cookies, doughnuts	18	*17*	19	*30*	24	*19*	11	*28*
Total number of breakfasts	**104**		**63**		**126**		**39**	

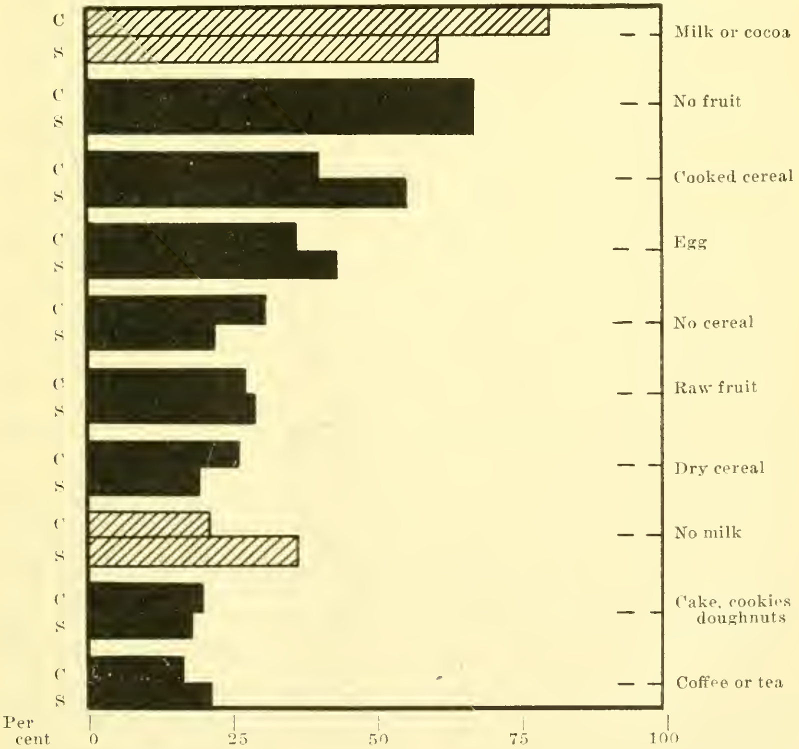


CHART 6. The Frequency with which the Most Usual Foods Appear in 104 CARVER and 126 SOUTHWICK Breakfast Menus of Children of Native and Mixed Parentage.

Noon meals

Contrasts between the sort of noon meal eaten when the child goes home and that carried to school are shown in Tables 13 and 14. So little difference was found between the lunches taken to school by the children of native parentage and those of foreign-born parentage that in Table 14 the data are presented for all children together. Very likely the children of foreign-born parentage demand lunches that will not seem different from those of the others. At any rate, inspection of lunch boxes brought to light no essential variation between the groups.

The home noon meals had hot foods, meat and potatoes being the most frequent items on the menus. The difference in milk utilization in the two

TABLE 13. Principal Items in Noon Meals at Home

Food	CARVER				SOUTHWICK			
	Native		Foreign		Native		Foreign	
	No.	*Per cent*	No.	*Per cent*	No.	*Per cent*	No.	*Per cent*
Meat	33	*66*	18	*38*	65	*79*	17	*52*
Potatoes	33	*66*	25	*53*	75	*89*	21	*64*
Vegetables not potato or leafy	12	*24*	12	*26*	27	*32*	3	*9*
No vegetables	9	*18*	14	*30*	4	*5*	12	*36*
No vegetable except potato	23	*46*	21	*45*	38	*44*	11	*33*
Potato and one vegetable	0	*0*	0	*0*	32	*38*	9	*27*
Egg	8	*16*	19	*40*	10	*12*	12	*36*
Puddings	12	*24*	19	*40*	33	*39*	5	*15*
Cake, cookies, doughnuts	16	*32*	29	*62*	13	*15*	10	*30*
Pie	29	*58*	5	*11*	19	*23*	4	*12*
Milk or cocoa	6	*12*	16	*34*	55	*65*	20	*61*
Coffee or tea	6	*12*	13	*28*	8	*10*	4	*12*
Total number of meals	**50**		**47**		**84**		**33**	

TABLE 14. Principal Items in School Lunches

Food	CARVER All children		SOUTHWICK All children	
	No.	*Per cent*	No.	*Per cent*
Sandwiches				
Meat	67	*39*	58	*47*
Egg	25	*15*	42	*34*
Jelly	30	*18*	23	*19*
Egg	15	*9*	2	*2*
Fruit	79	*46*	62	*50*
Two or more sweets	109	*64*	33	*27*
Three sweets	55	*32*	5	*4*
Milk or cocoa	15	*9*	40	*32*
Total number of school lunches	**170**		**124**	

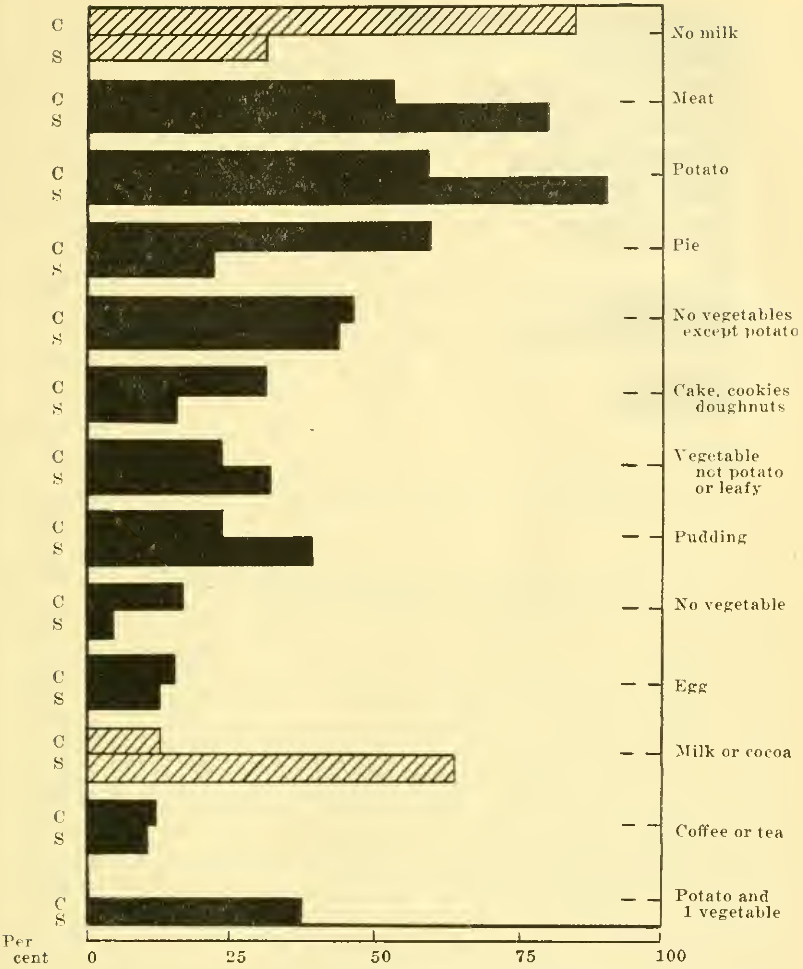


CHART 7. The Frequency with which the Most Usual Foods Appear in 50 CARVER and 84 SOUTHWICK Menus of Noon Meals Eaten at Home, by Children of Native and Mixed Parentage.

towns is evident in these meals, 65 per cent of the Southwick children of native stock having milk or cocoa, but only 12 per cent of those in Carver. Pie was the popular Carver sweet, appearing in 58 per cent of the home noon meals of the children of native parents. In Southwick more puddings than pies were used in these families, 39 per cent of the meals having puddings and 23 per cent pie. Cake, cookies, or doughnuts (cookies less often than the others) were served at 32 per cent of these Carver home noon meals, and 15 per cent of the Southwick ones.

In the school lunches of Carver sweets occupied a striking place, 64 per cent of the lunches having two or more sweets—two pieces of pie, or pie and cake, or two pieces of cake, or cake and doughnuts, or pie and doughnuts—and one-third of the lunches (32 per cent) contained three such sweets.

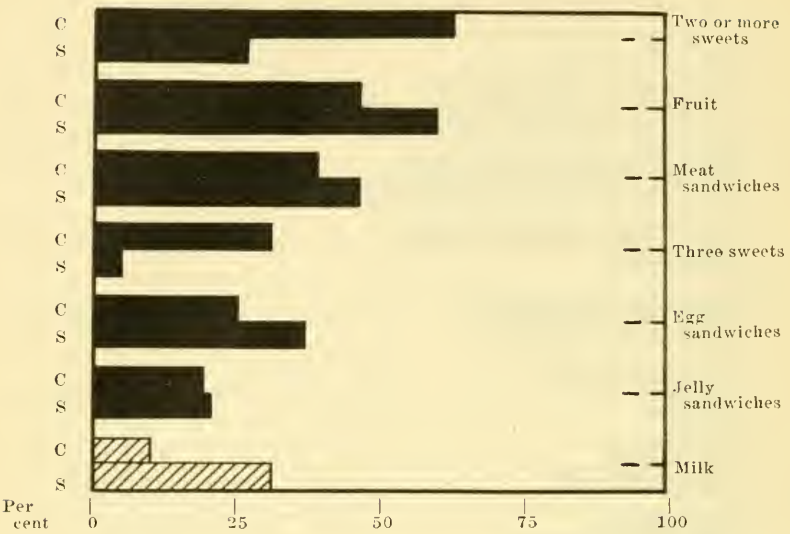


CHART 8. The Frequency with which Certain Foods Appear in the Menus of 170 CARVER and 124 SOUTHWICK Box Lunches of Children of Native, Mixed and Foreign-born Parentage.

Southwick school lunches did not have so many sweets, only one-fourth (23 per cent) of the noon meals eaten at the schoolhouse having two sweets, and but five out of 124 lunches having three sweets. In either town a box lunch without at least one sweet was practically an unheard-of thing.

In general the child who goes home for his noon meal fares better than the one who must carry it. Although home noon meals are far from ideal, they do have at least one hot dish, and the amount of pie and cake is not quite so great as it is in the lunch box. The types of school lunch eaten by these rural school children can best be judged from the menus below, which were selected from the records at random.

CARVER

Age of Child	Menu
Eight	Salmon sandwich Bacon sandwich Cake Pie Prunes
Nine	Crackers with jelly Cake Prune pie Orange
Ten	Eggs—hard boiled Meat sandwich Cookies Pie Cake
Eleven	Meat sandwich Cookies Pie Cake
Twelve	Peanut butter sandwich Cake Candy

SOUTHWICK

Age of Child	Menu
Six	Egg sandwich Apple Cookies Milk
Eight	Lettuce and egg sandwich Cake Cooky Apple Milk
Nine	Jelly sandwich Canned peaches Apple
Twelve	Egg sandwich Cake Pie Canned fruit
Thirteen	Meat sandwich Cheese sandwich Doughnuts Orange

Another difficulty with the box lunch is that the child makes eating an almost continuous performance. He eats something during morning recess, more at noon, again at afternoon recess, and saves something to eat on the way home. Only one teacher was found who had attempted any regulation of this indiscriminate access to the lunch, and she was having a trying time with both children and parents. One mother said to the writer, "I won't let any teacher make my child go hungry."

In neither town was a hot dish or drink served at noon regularly throughout the school year. The Carver teachers did, on their own initiative, provide either cocoa or soup during the months of January and February. In one instance, the teacher prepared the cocoa at home, brought it several miles to the schoolhouse, and heated it on a grill which she also provided. She stated that, even at the low price of ten cents a week, not all the children took advantage of the service. "It seems that only those who need it least take it—the ones who would be well provided for by their parents anyhow."

Evening Meals

The menus of the evening meals are presented in Table 15 and those of the children of native and mixed parentage are also shown in Chart 9.

TABLE 15. Principal Items in Evening Meals

Food	CARVER				SOUTHWICK			
	Native		Foreign		Native		Foreign	
	No.	*Per cent*	No.	*Per cent*	No.	*Per cent*	No.	*Per cent*
Meat	81	*84*	51	*82*	61	*54*	15	*47*
Potato	76	*78*	56	*90*	76	*68*	29	*91*
Vegetables not potato or leafy	57	*59*	37	*60*	59	*53*	5	*16*
No vegetables except potato	27	*28*	28	*45*	31	*28*	16	*50*
Puddings	21	*22*	25	*40*	25	*22*	0	*0*
Cake, cookies, doughnuts	50	*52*	29	*47*	53	*47*	19	*59*
Pie	44	*45*	12	*19*	10	*9*	8	*25*
Milk or cocoa	34	*35*	15	*24*	87	*78*	17	*53*
Coffee or tea	21	*22*	17	*27*	9	*8*	5	*16*
Total number of evening meals	97		62		112		32	

Meat headed the list for the Carver children of native parentage, while milk took first place in Southwick. Potatoes were high in both towns. Thirty-five per cent of these Carver evening menus contained milk or cocoa; 78 per cent of the Southwick ones. In desserts Carver greatly exceeded Southwick. In 97 Carver evening meals there were 115 desserts—21 puddings, 44 pies, and 50 pieces of cake, cookies, or doughnuts. Southwick in 112 evening meals had only 88 desserts—25 puddings, 10 pieces of pie, and 53 other sweets.

Food for entire day

The principal items in the rations for an entire day appear in Table 16 and are given in Chart 10 for the children of native and mixed parentage and in Chart 11 for those of foreign-born parentage. Typical day's menus are given later in the text.

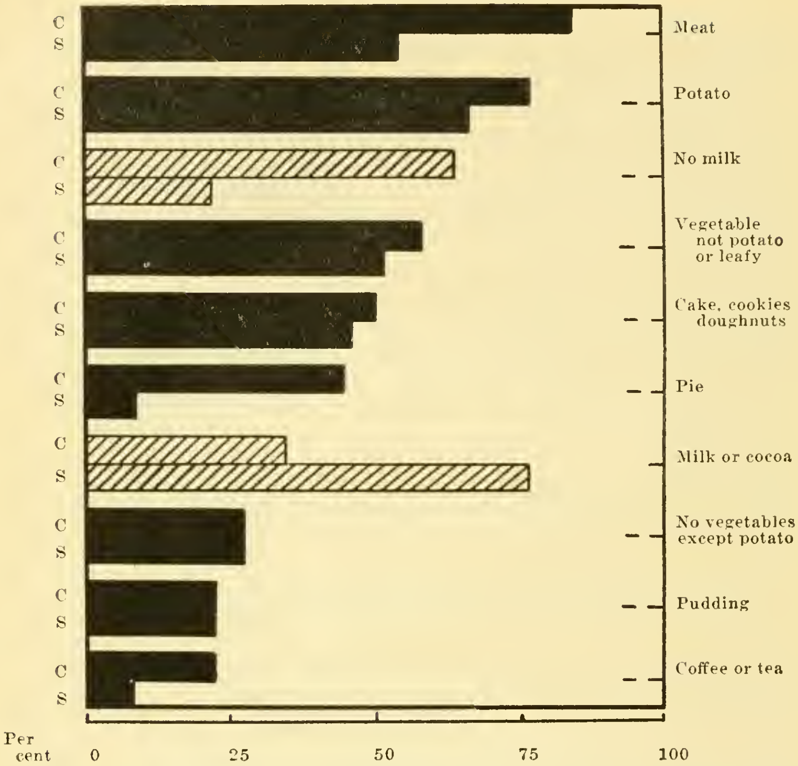


CHART 9. **The Frequency with which Certain Foods Appear in the Menus of 97 CARVER and 112 SOUTHWICK Suppers of Children of Native and Mixed Parentage.**

Table 16. Principal Items in Menus for Entire Day

Food	CARVER				SOUTHWICK			
	Native		Foreign		Native		Foreign	
	No.	*Per cent*	No.	*Per cent*	No.	*Per cent*	No.	*Per cent*
Meat	79	*84*	48	*80*	83	*89*	14	*52*
Potato	86	*91*	55	*92*	89	*94*	27	*100*
Vegetables not potato or leafy	54	*57*	28	*47*	64	*69*	6	*22*
Potato and one vegetable	32	*34*	13	*22*	43	*46*	16	*59*
Potato and two or more vegetables	32	*34*	15	*25*	30	*32*	1	*4*
Leafy vegetables	38	*40*	10	*17*	22	*24*	15	*56*
Fruit or raw vegetable	82	*87*	27	*45*	74	*80*	6	*22*
Egg	55	*59*	33	*55*	46	*49*	17	*63*
Pudding	26	*27*	29	*48*	41	*44*	5	*19*
Cake, cookies, doughnuts	62	*66*	47	*78*	61	*66*	19	*70*
Pie	58	*61*	28	*47*	22	*24*	9	*33*
Three or more sweets	59	*63*	52	*87*	23	*25*	5	*19*
Milk or cocoa	59	*63*	36	*60*	87	*91*	25	*93*
Coffee or tea	24	*25*	39	*65*	14	*15*	7	*26*
Total number of meals	**94**		**60**		**93**		**27**	

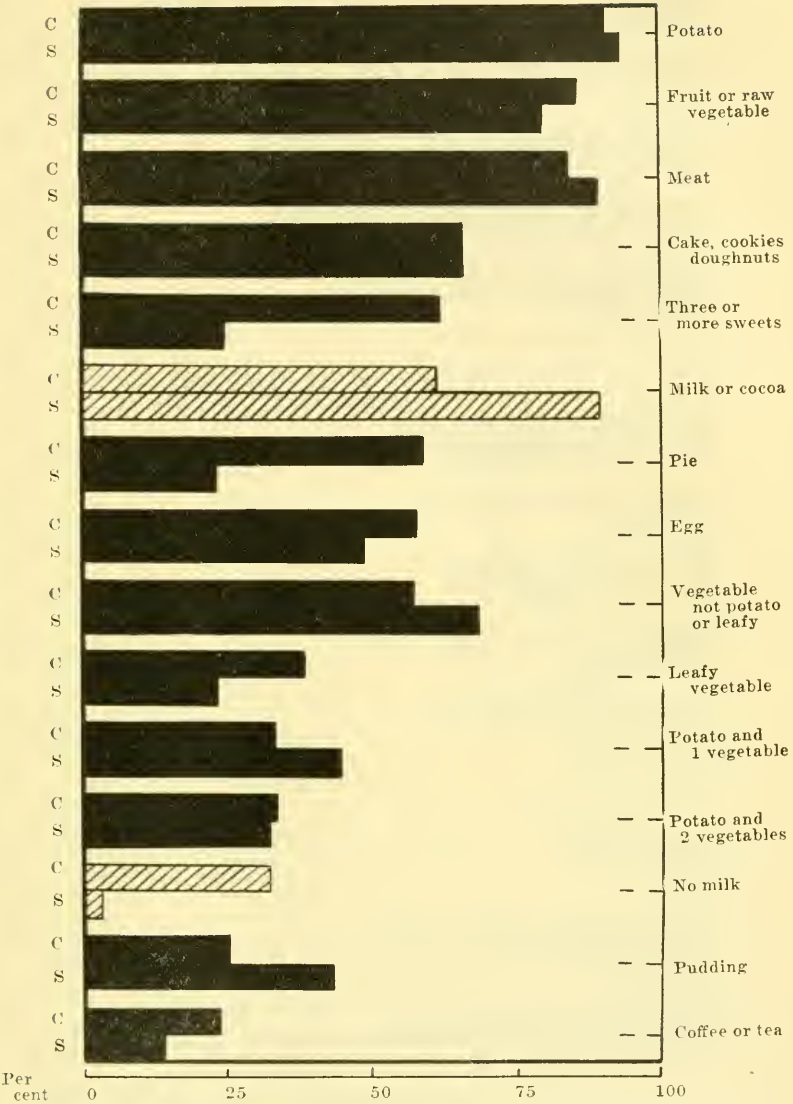


CHART 10. The Distribution of the Principal Items in the Day's Meals of 94 CARVER and 93 SOUTHWICK Children of Native and Mixed Parentage.

In the records of 94 Carver children of native stock for whom a day's menus were secured, potatoes were the most frequent item on the list; fruit or raw vegetables (mainly apples and oranges) next: meat third; cake, cookies, and doughnuts fourth; milk or cocoa fifth; pie sixth; then eggs, vegetables, leafy vegetables, puddings; and last coffee or tea.

In the day's menus for 93 Southwick children of native stock, potatoes took first place as in Carver: milk, which was fifth in Carver, was second in South-

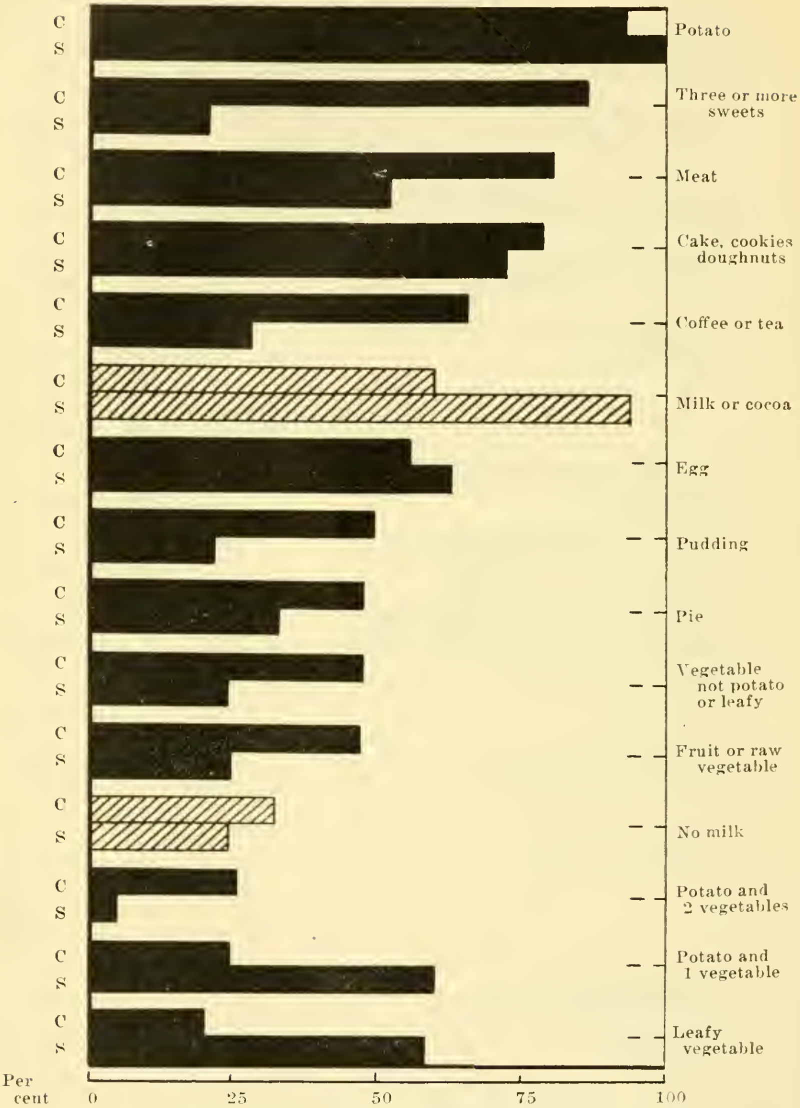


CHART 11. The Distribution of the Principal Items in the Day's Meals of 60 CARVER and 27 SOUTHWICK Children of Foreign-born Parentage.

wick; meat third; fruit or raw vegetables fourth; other vegetables fifth; cakes and doughnuts sixth; eggs seventh; puddings eighth; leafy vegetables and pie tied for ninth place; and again coffee and tea came last, being used in Southwick even less often than in Carver.

The data on the day's meals of children of foreign-born parentage are presented in table and chart, but here, as elsewhere, no interpretations of data based on such heterogeneous groups are given.

Typical day's menus:

CARVER

Age of child		Menu
Nine	Breakfast—	Oatmeal Pancakes Egg Milk
	Box lunch—	Cheese sandwich Doughnuts Cake Pie
	Supper—	Meat Potatoes Cranberries Pie
Nine	Breakfast—	White bread toast Postum Cake
	Home noon meal—	Baked beans White bread Pickles Pie
	Supper—	Pork Macaroni Cake
Eleven	Breakfast—	Oatmeal White bread toast Marmalade Doughnuts
	Box lunch—	Meat sandwich Pie Cake Doughnut Orange
	Supper—	Meat Potatoes Spinach Lettuce Jello Milk
Twelve	Breakfast—	Baked beans Egg Oatmeal Milk
	Box lunch—	Peanut butter sandwiches Two pieces cake
	Supper—	Beef soup with vegetables Baked beans Cake
Thirteen	Breakfast—	Malt cereal White bread toast Orange Milk
	Box lunch—	Meat sandwich Jelly sandwich Orange
	Supper—	Clam cakes Potato and carrot hash Celery Lettuce with mayonnaise Apple pie Milk

SOUTHWICK

Age of child		Menu
Seven	Breakfast—	Cornflakes Spaghetti White bread toast Coffee
	Home noon meal—	Pot roast Potatoes Tapioca pudding Cake Milk
	Supper—	Ham Potatoes Pie Milk
Eight (a)	Breakfast—	Oatmeal Whole wheat bread toast Milk
	Home noon meal—	Tomato soup Whole wheat bread Tapioca pudding Milk
	Supper—	Roast beef Boiled potatoes String beans Asparagus Whole wheat bread Plain cake Milk
Ten	Breakfast—	Oatmeal Milk
	Box lunch—	Ham sandwiches Cake Apple
	Supper—	Fried potatoes Prunes Cake Milk
Eleven	Breakfast—	Ham and eggs Oatmeal Banana Milk
	Home noon meal—	Beef Potatoes Baked beans Eggs Milk
	Supper—	Beef Potatoes Cereal Cake Milk
Thirteen	Breakfast—	Fish Eggs Milk
	Home noon meal—	Corned beef Potatoes Milk
	Supper—	Macaroni and cheese Tomatoes Bread pudding Milk

(a) This little girl had the highest total diet score of any in the two towns. Apples and oranges were given her as mid-morning and mid-afternoon lunches.

PART III. HEALTH STATUS

Two methods were used in the effort to determine whether or not any definite correlation could be established between the food habits which have been described and the state of health of the children: first, the records of the physical examinations given by the children's clinic of the Division of Tuberculosis of the Massachusetts Department of Health; and second, examination of the teeth by a dental hygienist.

Clinic Examinations

The physical examinations given at the clinic sessions are quite frankly made for the purpose of discovering cases of tuberculosis. State of nutrition, as such, is not emphasized and the records on this point are not sufficient to be very illuminating. Few cases of disease of any type were reported for either Carver or Southwick. Of the Carver children for whom records of dietary history and food habits were obtained, only one case of heart disease, one of hilum tuberculosis, and three of malnutrition were discovered at the clinic; among the Southwick children, one case of hilum tuberculosis and one of malnutrition.

The general appearance of nine of the 134 Carver children who were examined was marked "fair" instead of "good" as was that of the others; six were reported as having flabby muscles, three of these being the children diagnosed as cases of malnutrition; 18 were found to have bad tonsils; and 12, diseased adenoids.

In Southwick, of 110 children examined, three were reported as having "poor" general appearance; two, flabby muscles; 16, bad tonsils; and 5, diseased adenoids.

Weight

The height and the weight of each child were taken at the clinic session, and percentage of overweight or underweight computed from the weight-height-age standards of the Baldwin-Wood tables. Such records were obtained in Carver for 83 of the 95 children of native stock and 51 of the 60 of foreign-born parentage; in Southwick, for 84 of the 93 of native stock and 26 of the 27 of foreign-born parentage.

The tabulation below shows, for each town, the number of children 10 per cent or more overweight or underweight.

	CARVER				*SOUTHWICK*			
	Native		Foreign		Native		Foreign	
	No.	*Per cent*	No.	*Per cent*	No.	*Per cent*	No.	*Per cent*
UNDERWEIGHT								
10 per cent or more	15	*18*	13	*25*	8	*10*	1	*4*
15 per cent or more	8	*10*	3	*6*	2	*2*	1	*4*
OVERWEIGHT								
10 per cent or more	8	*10*	2	*4*	21	*25*	1	*4*
15 per cent or more	5	*6*	1	*2*	17	*20*	0	*0*
Number of children	**83**		**51**		**84**		**26**	

The numbers in the above classifications are much too small to permit valid comparisons with diet scores. A study of the records of the individual children points to the conclusion that, in overweight, quantity of food consumed rather than the quality of the diet is the chief factor. The diet scores of the overweight children do not fall into any particular numerical group but are scattered throughout the entire range of scores.

Two of the most extreme cases of underweight were children barely convalescent from serious illness; a third was that of a girl suffering from marked hyperthyroidism—the only case of endocrine imbalance reported in either town. For the other cases of underweight, no explanation is to be found in the available data.

Age does not appear to be a factor in either over- or underweight. In the distributions of weight by age the frequencies are scattering.

Dental Examinations

The examinations of the children's teeth were made painstakingly and slowly, in order that no defect might go unrecorded. Eight days were required to examine the pupils in the Carver schools and 14 days in Southwick. More time was needed in Southwick because of the distances to be travelled between school buildings and also because of the larger proportion of white children. Complete examinations were not made of the teeth of the colored children, since those records were not to be included among the data of the study. The colored children were kept in the examining chair only long enough to look at the four first permanent molars. In this way the possibility of giving offense to the colored families was avoided without wasting an undue amount of the hygienist's time.

The dental examinations were made with an explorer especially designed for the detection of fissures—the Gillett explorer, number one. It is not only extra fine and sharp but it also has an angle that permits easy access to the grooves of the molars.

The conditions of work were far from what might be desired,—three chairs, a portable headrest loaned from the Forsythe Dental Infirmary of Boston, mirrors and probes, with denatured alcohol in a half pint milk bottle as the sterilizer, and paper napkins for towels. In Southwick especially, the light in the schoolrooms was often so poor it made the work difficult and fatiguing for the hygienist. She spared no effort in her wish to make adequate and thorough examinations, and it is felt that these dental records give the most accurate information of any presented in this entire report.

All the teeth of 168 white children in Carver and 232 in Southwick were examined. Of these, 139 from Carver and 113 from Southwick were children whose homes were visited and for whom dietary records were secured.

Evidences of care by a dentist were found in the mouths of only 24 (23 per cent) of the 105 Carver children of native and mixed parentage, and 26 (23 per cent) of the 115 Southwick children of similar parentage. Among the children of foreign-born parentage, 8 (13 per cent) of the 63 from Carver and 14 (12 per cent) of the 117 from Southwick had evidences of previous dental repair work. These figures are naturally exclusive of possible extractions of temporary teeth by a dentist. It is not a matter for amazement that so few of these children had been taken to a dentist. Neither Carver nor Southwick has a resident dentist and very many of the parents, even if they wished to do so, would find it difficult to spare the time or the money necessary to take the children to a city for dentistry. Dental care in rural regions is notoriously even harder to obtain than a physician's services.

Unfilled cavities

The condition of the teeth of all the white children of Carver and Southwick, as indicated by the number of permanent teeth having unfilled cavities, is shown in Tables 17 and 18, and separately for children of native and mixed parentage in Tables 19 and 20. The younger children, of course, did not yet have many permanent teeth. Nevertheless, since the proportions of younger children are essentially the same in the two towns, the conclusions which

TABLE 17. Unfilled Cavities in Permanent Teeth of 168 Carver Children

Age to nearest birthday	Number in group	Number of permanent teeth having unfilled cavities											
		None	1	2	3	4	5	6	7	8	9	10	More than 10
6	3	1	0	2	0	0	0	0	0	0	0	0	0
7	23	11	2	3	4	2	1	0	0	0	0	0	0
8	19	3	4	3	4	3	1	1	0	0	0	0	0
9	23	4	3	6	3	6	1	0	0	0	0	0	0
10	15	3	2	2	3	4	0	0	0	0	0	0	1
11	15	2	3	0	1	4	2	0	1	0	0	0	2
12	30	3	2	6	6	5	1	2	1	0	1	1	2
13	19	0	1	2	3	1	1	1	1	2	3	0	4
14	14	1	3	2	2	2	0	2	0	0	0	0	2
15	4	0	2	0	1	0	0	0	0	0	0	0	1
16	3	0	0	0	0	0	0	2	0	0	0	1	0
All ages	**168**	**28**	**22**	**26**	**27**	**27**	**7**	**8**	**3**	**2**	**4**	**2**	**12**
Per cent	*100*	*17*	*13*	*16*	*16*	*16*	*4*	*5*	*2*	*1*	*2*	*1*	*7*

TABLE 18. Unfilled Cavities in Permanent Teeth of 232 Southwick Children

Age to nearest birthday	Number in group	Number of permanent teeth having unfilled cavities											
		None	1	2	3	4	5	6	7	8	9	10	More than 10
6	18	13	2	1	1	1	0	0	0	0	0	0	0
7	23	16	3	1	3	0	0	0	0	0	0	0	0
8	25	14	3	6	1	1	0	0	0	0	0	0	0
9	30	10	8	9	3	0	0	0	0	0	0	0	0
10	28	5	5	8	4	5	1	0	0	0	0	0	0
11	29	9	4	8	2	2	1	1	0	0	1	0	1
12	22	5	4	5	5	0	1	1	1	0	0	0	0
13	24	3	9	1	5	2	0	1	0	2	0	0	1
14	15	4	1	0	1	4	1	1	1	1	1	0	0
15	14	1	3	1	2	2	2	0	0	2	0	0	1
16	2	0	0	0	1	0	0	0	0	1	0	0	0
17	2	0	1	0	0	0	0	1	0	0	0	0	0
All ages	**232**	**80**	**43**	**40**	**28**	**17**	**6**	**5**	**2**	**6**	**2**	**0**	**3**
Per cent	*100*	*35*	*18*	*17*	*12*	*7*	*3*	*2*	*1*	*3*	*1*	*0*	*1*

may be reached from Tables 17, 18, 19 and 20 are not to be minimized on account of the inclusion of data on children having few permanent teeth erupted.

Considering all white children, 17 per cent in Carver and 35 per cent in Southwick had no unfilled cavities in permanent teeth. Among the children of native and mixed parentage the conditions were slightly better, 26 per cent in Carver and 41 per cent in Southwick having no unfilled cavities in permanent teeth.

Table 19. Unfilled Cavities in Permanent Teeth of 105 Carver Children of Native and Mixed Parentage

Age to nearest birthday	Number in group	Number of permanent teeth having unfilled cavities											
		None	1	2	3	4	5	6	7	8	9	10	More than 10
6	2	1	0	1	0	0	0	0	0	0	0	0	0
7	19	10	2	2	3	1	1	0	0	0	0	0	0
8	11	3	3	1	2	1	1	0	0	0	0	0	0
9	17	4	3	5	0	4	1	0	0	0	0	0	0
10	8	3	1	0	1	3	0	0	0	0	0	0	0
11	10	2	3	1	0	3	1	0	0	0	0	0	0
12	21	3	2	3	6	4	1	0	0	1	1	0	0
13	7	0	1	1	1	1	0	0	0	2	1	0	0
14	7	1	2	1	2	0	0	0	0	0	0	0	1
15	1	0	1	0	0	0	0	0	0	0	0	0	0
16	2	0	0	0	0	0	0	1	0	0	0	1	0
All ages	**105**	**27**	**18**	**15**	**15**	**17**	**5**	**1**	**0**	**3**	**2**	**1**	**1**
Per cent	*100*	*26*	*17*	*14*	*14*	*16*	*5*	*1*	*0*	*3*	*2*	*1*	*1*

Table 20. Unfilled Cavities in Permanent Teeth of 115 Southwick Children of Native and Mixed Parentage

Age to nearest birthday	Number in group	Number of permanent teeth having unfilled cavities											
		None	1	2	3	4	5	6	7	8	9	10	More than 10
6	11	8	1	1	0	1	0	0	0	0	0	0	0
7	18	12	2	1	3	0	0	0	0	0	0	0	0
8	14	8	2	3	0	1	0	0	0	0	0	0	0
9	12	8	1	2	1	0	0	0	0	0	0	0	0
10	11	1	2	3	1	3	1	0	0	0	0	0	0
11	14	4	2	4	1	1	0	1	0	0	1	0	0
12	10	3	2	3	2	0	0	0	0	0	0	0	0
13	13	2	4	1	3	2	0	1	0	0	0	0	0
14	4	1	0	0	0	1	0	1	0	0	1	0	0
15	5	0	0	0	2	0	2	0	0	1	0	0	0
16	2	0	0	0	1	0	0	0	0	1	0	0	0
17	1	0	0	0	0	0	0	1	0	0	0	0	0
All ages	**115**	**47**	**16**	**18**	**14**	**9**	**3**	**4**	**0**	**2**	**2**	**0**	**0**
Per cent	*100*	*41*	*14*	*16*	*12*	*7*	*3*	*3*	*0*	*2*	*2*	*0*	*0*

Sixty-one per cent of all white Carver school children had from one to four unfilled carious permanent teeth, and 22 per cent had five or more such teeth. Fifty-four per cent of all white children in Southwick had from one to four unfilled carious permanent teeth, while but 11 per cent had five or more.

Of the Carver children of native stock, 61 per cent (the same as for all children in that town) had from one to four permanent teeth with unfilled cavities; of the corresponding group in Southwick, 49 per cent had from one to four such permanent teeth. For the children having five or more permanent teeth with unfilled cavities, the difference between Carver and Southwick is not so great among those of native stock as among all children, being 13 per cent for Carver and 10 per cent for Southwick. The very poor teeth found among the Finnish children of Carver are chiefly responsible for the larger number of children in Carver who have five or more permanent teeth with unfilled cavities.

The significant differences here are those found among the children of native stock, where 41 per cent of the Southwick children have no permanent teeth with unfilled cavities, against 26 per cent in Carver; and where 61 per cent of Carver's children and 49 per cent of Southwick's have from one to four permanent teeth with unfilled cavities.

TABLE 21. Condition of the Four First Permanent, or Six-year Molars of All White Children

Condition of molars	Number of children	
	CARVER	SOUTHWICK
All unerupted	4	7
No fissures: number of molars carious or extracted		
1	0	0
2	0	0
3	1	1
4	67	37
No carious or extracted: number of molars with fissures		
1	1(a)	1(b)
2	4(a)	4(c)
3	2	3
4	14	65
One or more fissures: number of molars carious or extracted		
1	19	40
2	26	44
3	27	24
4	3	6
Total number of children	168	232

(a) One child with one molar unerupted.
(b) Three molars unerupted.
(c) All with two molars unerupted.

Six-year molars

Inasmuch as the various teeth are not all equally prone to decay, a measure was sought which would avoid errors arising from comparisons between teeth with a greater tendency to decay and those that have a lesser tendency to decay; as, for example, molars and incisors. The four first permanent, or six-year, molars have, therefore, been selected as the teeth to be used in making comparisons between conditions of teeth and diet. In all except the very youngest pupils, all four of these molars were erupted, as may be seen from Tables 21 and 22.

The word "cărious" is used to include both filled and unfilled cavities. The purpose of these tabulations is not to list dental repair work which should be attended to, but to discover if possible a relationship between teeth and dietary habits. From this point of view, a filled cavity is of the same significance as an unfilled one. It was not feasible to make a study of size or location of cavities, although such data would be of considerable interest. Examination of the original dental record blanks indicates that the cavities in the teeth of Carver children average larger than those in the teeth of the Southwick children.

The molars have been classified according to the number of fissures and cavities. No child was discovered in Carver or Southwick who had all four

TABLE 22. Condition of the Four First Permanent, or Six-year Molars of Children of Native and Mixed Parentage Aged Seven Years, Six Months, and Over

Condition of molars	Number of children	
	CARVER	SOUTHWICK
All unerupted	0	0
No fissures: number of molars carious or extracted		
1	0	0
2	0	0
3	1	0
4	27	16
No carious or extracted: number of molars with fissures		
1	0	0
2	2(a)	0
3	2	2
4	8	21
One or more fissures: number of molars carious or extracted		
1	14	16
2	14	16
3	14	9
4	2	6
Total number of children	84	86

(a) One child with one molar unerupted.

TABLE 23. Condition of Four First Permanent Molars and Milk Scores, of 121 Carver Children from 8 to 17 Years of Age

Milk score	Condition of molars																							
	No fissures: number of molars carious or extracted								No molars carious or extracted: number of fissures								One or more fissures· number of molars carious or extracted							
	1		2		3		4		1		2		3		4		1		2		3		4	
	Nat.	For.	Nat.	For.	Nat.	For.	Nat.	For.	Nat.	For.	Nat.	For.	Nat.	For.	Nat.	For.	Nat.	For.	Nat.	For.	Nat.	For.	Nat.	For.
0—4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
5—8	0	0	0	0	0	0	7	1	0	0	0	0	0	0	0	0	0	0	1	1	3	0	0	0
9—12	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
13—16	0	0	0	0	1	0	7	17	0	0	1	0	1	0	3	0	6	2	7	4	7	4	0	0
17—20	0	0	0	0	0	0	6	4	0	0	1	0	0	0	1	0	1	0	4	1	2	2	0	0
21—24	0	0	0	0	0	0	4	6	0	0	0	0	0	0	3	0	2	0	1	1	1	2	0	0
Total	**0**	**0**	**0**	**0**	**1**	**0**	**25**	**31**	**0**	**0**	**2**	**0**	**1**	**0**	**7**	**0**	**10**	**2**	**14**	**7**	**13**	**8**	**0**	**0**

TABLE 24. Condition of Four First Permanent Molars and Milk Scores of 87 Southwick Children from 8 to 17 Years of Age

0—4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5—8	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
9—12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
13—16	0	0	0	0	0	0	1	5	0	0	0	0	0	0	4	1	0	1	3	1	3	1	0	0
17—20	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	2	0	1	0	0	0
21—24	0	0	0	0	0	0	7	1	0	0	0	0	1	0	15	2	7	2	8	5	5	2	2	0
Total	**0**	**0**	**0**	**0**	**0**	**0**	**9**	**7**	**0**	**0**	**0**	**0**	**1**	**0**	**20**	**3**	**8**	**3**	**14**	**6**	**11**	**3**	**2**	**0**

or even three of these teeth free from either fissure or caries. Four children in Carver and four in Southwick had one of these first permanent molars in perfect condition; i. e., no fissure or caries; three children in Carver had two perfect molars apiece, but no child in Southwick. Among the children of native and mixed parentage, four in Carver and two in Southwick had each one perfect molar; one Carver child had two perfect molars.

Twenty-one Carver children and 73 Southwick children, or approximately one-eighth of the Carver children and one-third of the Southwick children, had these first permanent molars free from caries; that is, with fissures as the only defect found. It is assumed that the molars which had been extracted were taken out because of caries, and in the tabulations the data on the two conditions have been presented together.

A separate computation has been made of the conditions of the molars of the children aged seven years and six months or over, thus omitting most of those having any of these molars still unerupted. Among the 142 Carver children, 66 or 46 per cent, and among the 191 Southwick children 35 or 18 per cent, had all four molars carious or extracted; of the children of native stock, 27 or 32 per cent of the 84 Carver children and 16 or 19 per cent of the 86 Southwick children had the molars all carious or extracted; while of those of foreign-born parentage, 39 or 67 per cent of the 58 children in Carver and 19 or 18 per cent of the 105 in Southwick also had the molars all either carious or extracted.

From the tables here presented it appears that in general the condition of the teeth, as typified by the condition of the four first permanent molars, is much better among the Southwick children, both native and foreign stock, than among the Carver children. Since it has been shown that this is not due to greater dental care, the reason has been sought in dietary habits. Tables 23 and 24 show for all children having both records available, the relation between condition of molars and milk scores, and Tables 25 and 26 present for children of native stock, the relation between condition of molars and diet scores.

In both these sets of tables, where data for Carver and Southwick are presented, the numbers are so small in the various subdivisions that it is impossible to arrive at any conclusions and reliance must be placed upon

Table 25. Condition of Four First Permanent Molars and Diet Scores of 73 Carver Children of Native and Mixed Parentage from 8 to 17 Years of Age

Diet score	Condition of molars											
	No fissures: number of molars carious or extracted				No molars carious or extracted: number of fissures				One or more fissures: number of molars carious or extracted			
	1	2	3	4	1	2	3	4	1	2	3	4
0—29	0	0	0	1	0	0	0	0	1	0	0	0
30—59	0	0	1	12	0	1	1	4	5	8	8	0
60—89	0	0	0	12	0	1	0	3	4	6	5	0
90—100	0	0	0	0	0	0	0	0	0	0	0	0
Total	**0**	**0**	**1**	**25**	**0**	**2**	**1**	**7**	**10**	**14**	**13**	**0**

TABLE 26. Condition of Four First Permanent Molars and Diet Scores, of 61 Southwick Children of Native and Mixed Parentage from 8 to 17 Years of Age

Diet score	Condition of molars											
	No fissures: number of molars carious or extracted				No molars carious or extracted: number of fissures				One or more fissures: number of molars carious or ex tracted			
	1	2	3	4	1	2	3	4	1	2	3	4
0—29	0	0	0	0	0	0	0	0	0	0	0	0
30—59	0	0	1	1	0	0	0	6	4	3	3	2
60—89	0	0	0	3	0	0	2	12	8	9	6	1
90—100	0	0	0	0	0	0	0	0	0	0	0	0
Total	**0**	**0**	**1**	**4**	**0**	**0**	**2**	**18**	**12**	**12**	**9**	**3**

the findings for the Carver and Southwick groups as a whole. Milk, as has been shown, is the outstanding food in which the Southwick scores excel those of Carver, the difference being fully as striking as that between the condition of the four first permanent molars of the children in the two towns.

Southwick has been a dairy town for many years, so that with its stable native population these present children of native parentage are, certainly so far as their teeth are concerned, reaping the benefits of their mother's use of an ample amount of milk. Carver, on the contrary, has not had an abundant milk supply, and its children have not had the advantages deriving from a general consumption of milk by the mothers during pregnancy.

PART IV. SUMMARY

In this field study of the elementary school children of the two rural Massachusetts towns of Carver and Southwick, carried out through visits to the homes and by means of dental and medical examinations, the following points are of special interest:

1. It is not possible to obtain by the survey method reliable data upon the food habits and practices of previous years. Regarding current practices, information can be secured which is sufficiently trustworthy to give a fair picture of the present situation, provided the inherent inaccuracies are recognized as a determining factor in the choice of statistical methods of interpretation.

2. The diets of the children of Carver and Southwick were judged by a standard having an optimum score of 100, in which 24 points were allowed for milk, 23 for cooked vegetables, 21 for fruit and raw vegetables, 14 for whole grain cereal foods, and 18 for meat and eggs. Graded on this basis, only 15 per cent of the children of Carver and 24 per cent of those of Southwick can be considered to have diets suited to their needs.

3. The best point in the Carver diets is the amount of fruit and vegetables. The poorest feature qualitatively is the inordinate amount of sweet foods such as cake, doughnuts, and pie.

Southwick's diets have milk as their great safeguard. Vegetables are not used nearly as often nor in as much variety as should be the case. For both towns the amounts of whole grain cereal foods are meager.

4. The housewives, chiefly through lack of knowledge of even the simplest principles of good nutrition, do not make provision for meeting the food requirements of growing children. The meals are planned almost solely from the point of view of the tastes of the adult members of the household, and the children have free access to anything on the family table, in quantity as well as in kind.

5. The medical examinations, having been made from the angle of incidence of tuberculosis, did not produce many data bearing on the state of nutrition or on the general health of the children.

6. In this study, therefore, the records of condition of teeth are the principal available data for evaluating states of nutrition. Since the dental examinations were conducted with extreme care and by an able hygienist, these data have a high degree of accuracy.

7. The six-year molars, the four first permanent molars, have been chosen as the teeth to be used for purposes of comparisons, thus obviating chances of error arising from data based on teeth with varying tendencies toward decay.

8. Judging both from the number of all permanent teeth with unfilled cavities, the size of the cavities, and the number of first permanent molars either carious or with fissures, the teeth of the children of Southwick were on the whole in much better condition than those of the Carver children. This is particularly true of the two groups of children of native stock.

9. The smallness of the numbers does not permit detailed classifications of condition of molars and diet, but the excellence of the teeth of the Southwick children as compared with those of the Carver children is believed to have as its chief causal factor the high milk consumption of Southwick and the low milk utilization of Carver. No other difference between the two towns—economic, social or dietary—has been found to explain the difference in the teeth.

10. Because of the many elements, hereditary and environmental, which affect the physical state of the individual, and the impossibility of isolating factors, let alone controlling them, relationships of cause and effect cannot here be demonstrated from the records of individual children. Nevertheless, large group differences are undoubtedly significant, and the objectives of this study were best attained in the presentation of material showing the positive correlation between milk consumption and condition of teeth.

PART V. APPENDIX

1. School blank
2. Home blank
3. Dental record form

SCHOOL RECORD

Name.. Born..

School.. Date..

UNDERLINE THE STATEMENTS WHICH ARE TRUE FOR YOU

I. My Health Habits

1. I usually get up—before 6:00—about 6:30—about 7:30
about 6:00—about 7:00—after 7:30

2. Before breakfast this morning—I drank a glass of water
I did not drink any water

3. Every day I usually drink—1 glass of water—3 glasses of water
2 glasses of water—4 glasses of water

4. I wash my hands before eating—always
usually
once in a while

5. I usually brush my teeth—before going to bed
before breakfast
after breakfast

6. I usually go to bed—about 7:00—about 8:00—about 9:00
about 7:30—about 8:30—later than 9:00

7. I usually sleep with my window open—the year round
when it is warm

8. I usually take a bath—once a week
twice a week
less than once a week

9. This morning—my bowels moved
my bowels did not move

10. Yesterday—my bowels moved
my bowels did not move

11. I have to take medicine for this—once in a while
often
nearly every day

II. My Activities

12. From home to school is—only a few steps—about one-half mile
about one mile—more than one mile

13. I have to start—before 7:30—about 8:30
about 8:00—after 8:30

14. At noon I usually—go home
eat my dinner at school

15. I usually play with the other children—before school
at morning recess
at noon
at afternoon recess

III. My Food Habits

16. For breakfast this morning I drank—cocoa, coffee, tea, postum, milk, water

17. For dinner at noon yesterday I drank—cocoa, tea, milk, water

18. For supper yesterday I drank—cocoa, tea, milk, water

SCHOOL RECORD—3—

19. Every day I usually eat—one vegetable besides potato
two vegetables besides potato
no vegetable except potato

20. I eat fruit or sauce—once a day
twice a day
less than once a day

21. I eat cereal—every morning
three or four times a week
almost never

22. For bread I eat—white bread
dark bread

23. I usually eat meat—three times a day—once a day
twice a day—less than once a day

24. I usually eat an egg—every day
three or four times a week
once a week

25. When I eat—I take lots of time
I eat fast

26. I usually—am hungry at meals
have to be coaxed to eat at meals

27. For breakfast this morning I had

Fruit, sauce	Bread, toast, muffins
Warm cereal, dry cereal	Milk, water, coffee, cocoa, postum
Potatoes, bacon, egg, other meat	Doughnuts, pie, cookies, cake

SCHOOL RECORD—4—

28. For supper last night I had

Soup, meat, eggs
Potato, another vegetable
White bread, dark bread
Milk, water, tea, coffee, cocoa
Pie, pudding, cake, cookies, sauce

Tell anything else you ate for supper last night..

29. For my dinner today (or yesterday) I had

....
....
....
....

30. I eat between meals—at recess—in the evening
after school—never, or almost never

31. When I eat between meals I usually eat

How much?	How much?
Candy..........................	Crackers..........................
Ice cream..........................	Fruit..........................
Bread and butter..........................	Cake, cookies, doughnuts..........................
Sandwich..........................	Milk, cocoa..........................

Tell anything else you eat between meals..

Serial No.

HOME RECORD

Surname Address Date..................1927

	1	2	3	4
	b	b	b	b

I. Pre-School History

A. *Mother's Diet in Pregnancy*				
1. Milk, amt. da.				
2. Potatoes x da.				
3. Other veg. x da.				
4. Leafy veg. x wk.				
5. Fruit, cooked x da.				
6. R. fr., veg., c. tom. x wk.				
7. Bread, wh. gr. x da.				
8. Cereals, wh. gr. x wk.				
9. Eggs x wk.				
10. Meat x da.				
B. *Infant Diet*				
1. Breast fed, mos.				
2. Fresh milk, began, mo.				
3. Raw, past., began, mo.				
4. Milk modifier or subst. Kind, began, mo.				
5. Other foods:				
a. Potatoes x da.				
b. Other veg. x da.				
c. Orange juice				
d. Bread or cereal, ref. or wh. gr. x da.				
e. Eggs x wk.				
f. Cod liver oil				

Serial No. HOME RECORD—2—

	1	2	3	4
C. *Diet*, 1-5 *yrs., inc.*				
1. Milk, amt. da.	______	______	______	______
. Potatoes x da.	______	______	______	______
3. Other veg. x da.	______	______	______	______
4. Leafy veg. x wk.	______	______	______	______
5. Fruit, cooked x da.	______	______	______	______
6. Fruit, raw x wk.	______	______	______	______
7. Bread or cer. wh. gr. x wk.	______	______	______	______
8. Eggs x wk.	______	______	______	______
9. Meat x wk.	______	______	______	______
10. Coffee, tea x da.	______	______	______	______

II. Present Use of Foods by Children

1. Milk, amt. da.				
fresh	______	______	______	______
canned	______	______	______	______
2. Potatoes x da.	______	______	______	______
3. Other veg. x da.	______	______	______	______
4. Leafy veg. x wk.				
summer	______	______	______	______
winter	______	______	______	______
5. Fruit, cooked x da.				
summer	______	______	______	______
winter	______	______	______	______
6. R. fr., veg., c. tom. x wk.				
summer	______	______	______	______
winter	______	______	______	______
7. Bread, wh. gr. x da.	______	______	______	______
8. Cereal, wh. gr. x wk.	______	______	______	______
9. Eggs x week	______	______	______	______
10. Meat x da.	______	______	______	______
11. Coffee, tea x da.	______	______	______	______

Serial No. HOME RECORD—3—

III. Related Health Habits and History

	1	2	3	4
1. Daily bowel movement				
2. Laxatives, etc. habitual, occasional				
3. Digestive upsets freq., seldom, never				
4. Bed at ____ p. m.				
5. Up at ____ a. m.				
6. Dentist at least yearly				
7. Eruption 1st tooth, mo.				

Serial No.

IV. Present Family Food Habits

1. Breakfast		2. Noon Meal		3. Evening Meal		4. Between Meals	
Typical Foods	Usual Meal	Typical Foods	Usual Meal	Typical Foods	Usual Meal	Typical Foods	Usual Foods
Fruit		Soup, stew		Soup, stew		Which chdn.	
Cereal, wh. gr.		Meat		Meat		piece	
Bread, wh. gr.		Potatoes		Potatoes		When	
Eggs		Other veg.		Other veg.			
Meat						Eat what	
Potatoes		Raw veg. or fruit		Raw veg. or fruit			
Beverage							
		Cooked fruit		Cooked fruit			
		Dessert—Pie		Dessert—Pie		Candy or	
Misc.		Pudding		Pudding		sweets	
		Cake		Cake			
		Beverage		Beverage		Misc.	
		Bread, wh. gr.		Bread, wh. gr.			
		Misc.		Misc.			
Time a. m.		Time		Time p. m.			

Serial No. HOME RECORD—5—

V. Family Data

A. Parents *B. Household*

	Father	Mother	Age	Male	Female
1. Occupation	…………	…………	0-1	…………	…………
2. Birthplace	…………	…………	1-6	…………	…………
3. Nationality or race	…………	…………	6-16	…………	…………
4. Approx. age	…………	…………	16+	…………	…………
5. Education	…………	…………			

C. Contributing Factors in Poor Nutrition:

1. Low income …………
2. Indifference …………
3. Ignorance …………
4. Poor discipline
5. Other conditions …………

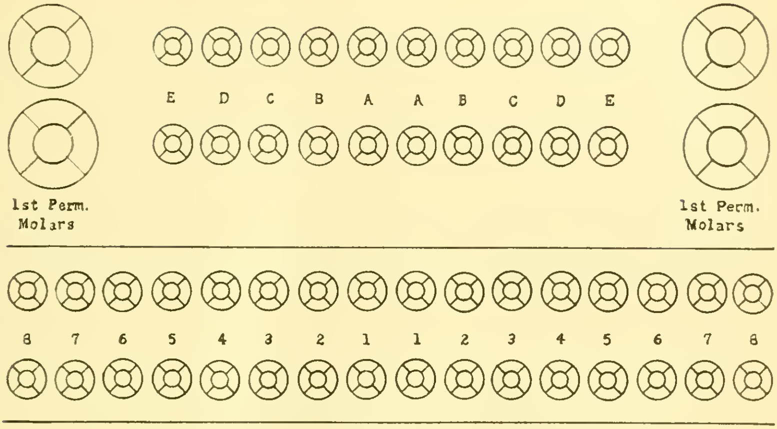
…………………………

D. Economic Aspects:

1. Residence: owned………… rented…………
2. Type residence: farm………… village………… other…………
3. Apparent income: high………… medium………… low………… very poor…………
4. Own cow………… buy milk…………

DENTAL RECORD

Serial No.......... Name............ Age ...... yrs....... mos.


E
D
C
B
A
A
B
C
D
E
1st Perm. Molars
1st Perm. Molars
8
7
6
5
4
3
2
1
1
2
3
4
5
6
7
8

SUMMARY

No. teeth: temporary.......................... permanent..........................

No. carious teeth: temporary.......................... permanent..........................

No. teeth with pits or fissures: temporary.......................... permanent..........................

Six-year molars: no. erupted..........................

cavities: filled.......................... unfilled..........................

pits or fissures: filled.......................... unfilled..........................

Occlusion: normal abnormal

Gingivae: normal inflamed badly inflamed

Prophylaxis: food deposits calculus

Other abnormality:

General condition of teeth: excellent good fair

poor very poor

PUBLICATION OF THIS DOCUMENT APPROVED BY THE
COMMISSION ON ADMINISTRATION AND FINANCE

3M-4-'28. No. 1961

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

Bulletin No. 242 April, 1928

Vigor in Production - Bred Flocks

By F. A. Hays and Ruby Sanborn

In pedigree breeding for high fecundity, the question of vigor is of paramount importance, because the mortality rate tends to become higher as egg production increases. In the Rhode Island Red flock studied, vigor was found to be independent of the fecundity traits, early maturity, high intensity, non-pause and high persistency; but to be reduced by eliminating broodiness. The most feasible practice for improving vigor is to breed only from those families showing the lowest mortality of pullets in the laying houses.

Requests for bulletins should be addressed to the

AGRICULTURAL EXPERIMENT STATION
AMHERST, MASS.

VIGOR IN PRODUCTION-BRED FLOCKS

By F. A. Hays, Research Professor of Poultry Husbandry, and
Ruby Sanborn, Research Assistant in Poultry Husbandry.

Introduction

In pedigree breeding for high fecundity the question of vigor is of paramount importance because the mortality rate tends to become higher as egg production increases. Without question, the complex physiological process of egg laying places the pullet under a severe test for vigor which may or may not shorten her life. Poultrymen and biologists are not familiar with the vast array of factors concerned, but the former are very eager to know how high vigor may be detected in the living bird.

High vigor may be defined as the possession of all those necessary qualities or characteristics that make possible a long and productive life in the hen. A number of common physical characteristics are made use of in culling operations, but just how much weight should be attached to these has never been demonstrated.

Pearl (1911) points out that adult mortality may be considered as an index of general vitality and constitutional vigor, and presents mortality records in the laying houses for a period of nine years.

Lippincott (1921) states that there are certain characteristics that are correlated with that maximum efficiency of all organs termed constitutional vigor but that these characters are relative rather than absolute. He makes reference to breed characters, head characters, body characters, etc.

Dryden (1921) emphasizes the fact that a hen may not inherit high vigor and that such a hen may break down under the strain of high production. This worker lays special stress on the value of high vigor as a necessary concomitant of inherited high fecundity.

Bittenbender (1922) suggests that both males and females should be selected for constitutional vigor and vitality, and that vitality, type and egg production are very closely correlated. Such body characters as type of head, beak, eyes, comb, body, breast, legs and toes may be used as indices of vigor.

Rice and Botsford (1925) write: "The use of strong, vigorous birds is essential, as it means better fertility and hatchability, and less mortality in chicks." These writers consider the head of the fowl as the best guide in selection for vigor.

At the present time there is need for well substantiated evidence on the relation of specific characteristics to vigor.

As the measure of vigor for these studies, mortality rate in the laying houses for a 365-day period has been used. This period begins when the pullets are housed at about 150 days of age and covers the pullet laying year only. Those families having the lowest mortality rate during the pullet laying year are thus considered to be the most vigorous.

In this bulletin consideration is given to two general groups of conditions affecting mortality in the laying houses: namely, those that may be controlled by methods of management, and those that may be controlled by methods of breeding. In the first class may be mentioned age of mothers and hatching dates; in the second group belong age at first egg, weight at first egg, persistency, production, etc. Knowledge of the relation of conditions or characteristics to mortality rate is useful to poultrymen in developing a management and breeding program to combine high fecundity and low mortality.

Birds Used

These studies cover a five-year period beginning with the flock hatched in 1922 and ending with the flock hatched in 1926. The birds are all pedigreed Rhode Island Reds that have been pedigree-bred since 1913 with no outside blood introduced since 1915. The greater proportion of the birds have been bred for high fecundity, with only a limited number used for inbreeding, broodiness and color studies.

The method of management has not been changed during the period reported. All chicks have been raised on a clean range under four-year rotation. Quarantine measures have been regularly employed to exclude disease. Hatching dates have been kept constant from year to year. There are eight hatches each year at weekly intervals, beginning March 25 and ending May 15. About 250 day-old chicks are placed immediately on the range in each 10x12 brooder house with coal heater. All live chicks are placed in brooder houses and no culling is practiced. These chicks are driven outside each day beginning with the fourth day.

The character of the ration and the method of feeding were kept constant throughout the period reported. Sexes are separated at about eight weeks and the birds are given free range of a large grassy area with trees and bushes for shade. In late summer green corn is cut and fed fresh daily. All pullets are taken to the laying houses when about 150 days old and housed according to hatching date in 30x30 open-front houses, 250 pullets per house. Cockerels are taken to winter quarters at the same time. All culling is done by families only. All physically normal sisters from desirable mothers are retained, and no pullets are culled in the laying house at any time.

Health Conditions

As previously noted, strict precautions have been taken to avoid disease epidemics and external and internal parasites. Clean ranges and scrupulously cleaned and disinfected houses and utensils were used throughout the period. The caretaker of young stock was not permitted to come in contact with adult birds and the caretaker of adult birds did not visit the growing range. Remedial measures were regularly employed to check all external parasites and worm treatments were given to adult stock. Yards about the laying houses are plowed up yearly and seeded to forage crops. Despite these precautions, some disease epidemics have occurred.

In September, 1922, chicken pox appeared in all young stock. It was a mild outbreak and terminated after a few weeks without serious effects as far as could be discerned.

No disease epidemics appeared in the 1923 flock. The flock hatched in 1924 suffered heavy losses from roup which appeared early in March, 1925, and caused nearly 60 per cent of the losses for the year. The flock of 1925 suffered from an outbreak of pox which later developed into roup. First cases of pox appeared about October 19, 1925, and autogenous vaccine was administered to all birds February 19, 1926. Losses appeared to be greatly reduced by the vaccine. The flock hatched in 1926 was afflicted with no recognized disease outbreaks. All stock has tested free of Bacillary White Diarrhoea throughout the period.

MASS. AGRICULTURAL EXPERIMENT STATION
POULTRY BREEDING UNDER QUARANTINE

Quarantine measures as carried out with the Massachusetts Experiment Station flock afford the safest preventive of infectious and contagious diseases. Under New England conditions quarantine measures are an essential part of successful management.

Clean, vigorous chicks can be most economically produced on rolling land with abundant grass and shade. Crowding is often disastrous. A systematic three- or four-year rotation of range should be practiced to avoid diseases and parasites.

Experimental Results

Mortality rate during the pullet laying year is employed as the measure of vigor in these studies. An outbreak of pox and roup in the flocks hatched in 1924 and 1925 has increased the mortality in the laying houses beyond the true figure if no epidemic appeared. During the years 1922, 1923 and 1926 there were no infectious disease outbreaks.

1. *Age of Mothers in Relation to Vigor of Daughters.*

Mothers of the pullets housed are divided into two classes; namely, pullet mothers and hen mothers. The latter group includes largely yearlings, a few two-year-olds and a very small number of older hens. The table below gives the detailed figures by hatching years, with calculations made by families:

Considering first the mortality rate in all chicks for the first eight weeks of life, the fact is noted that losses from pullet mothers were consistently greater than losses from hen mothers in the last three years reported. The average percentage loss from pullet mothers is 2.78±1.70 per cent less than from hen mothers for the hatching year of 1923. This difference is not significant and is probably due to chance alone. Records of losses to eight weeks are not available on the 1922 flock.

A wide range in mortality rate from pullet mothers is shown in the four-year period considered. The smallest losses occurred in 1923, with only 5.58 per cent. In the years that followed the morality rate rose, reaching a maximum of 22.66 per cent in 1925. Losses for the first eight weeks in chicks from hen mothers were lowest in 1924, being 6.06 per cent. The greatest losses occurred in 1925 and amounted to 11.81 per cent. Comparing pullet and hen mothers, the data show that chicks from pullet mothers are more variable in death rate than those from hen mothers. There is also evidence of a greater percentage of poor breeders among the pullets when judged by mortality rate in chicks.

The grand average for the four years is interesting. The 128 pullet mothers tested gave 2103 chicks, while the 205 hen mothers tested gave 3538 chicks. The grand average mortality rate in chicks for eight weeks is 15.50±2.26 per cent from pullet mothers and 8.88±.69 per cent from hen mothers. The difference amounts to 6.62±2.36. While this difference is relatively large it is less than three times as great as its probable error and offers inconclusive statistical evidence of superiority of hen mothers over pullets in breeding high vigor chicks.

In table 1, the relation of age of mothers to vigor of offspring measured by mortality rate of daughters in the laying houses may be studied. The mortality rate in the laying houses is greater in the daughters of pullet mothers in three out of five years but only for 1922 is the difference significant. For 1922 the mortality rate from hen mothers is 13.20±2.89 below that of pullet mothers and its magnitude is more than four times as great as its probable error. In 1923 and 1926 the losses from hen mothers were slightly, though not significantly greater than from pullet mothers.

Average mortality rate in daughters from 172 pullet mothers in the five-year period is 34.48±3.54 per cent. Average mortality rate in daughters from 248 hen mothers in the five-year period is 31.74±2.94 per cent. The difference is 2.74±4.60 and must be due to random sampling alone and not to inherent causes.

Table 1—Relation of Age of Mothers to Vigor of Offspring

Hatching Year	Pullet Mothers				Hen Mothers				Total Mothers			
	Number of Mothers and Chicks	*Mortality to 8 Weeks Per cent*	Number of Pullets Housed	*Mortality in Laying House Per cent*	Number of Mothers and Chicks	*Mortality to 8 Weeks Per cent*	Number of Pullets Housed	*Mortality in Laying House Per cent*	Number of Mothers and Chicks	*Mortality to 8 Weeks Per cent*	Number of Pullets Housed	*Mortality in Laying House Per cent*
1922	44	....	342	*37.72 ± 2.12*	43	....	310	*24.52 ± 1.96*	87	....	652	*31.44 ± 1.50*
1923	30 448	*5.58 ± 1.41*	212	*25.00 ± 3.28*	43 706	*8.36 ± .96*	310	*27.10 ± 1.98*	73 1154	*7.28 ± .81*	522	*26.25 ± 1.56*
1924	22 396	*11.11 ± 1.50*	158	*56.96 ± 3.40*	55 1006	*6.06 ± .74*	410	*49.76 ± 2.13*	77 1402	*7.49 ± .70*	568	*51.76 ± 1.81*
1925	28 534	*22.66 ± 2.20*	186	*26.34 ± 2.78*	57 1084	*11.81 ± 1.09*	431	*22.97 ± 1.79*	85 1618	*15.39 ± 1.13*	617	*23.99 ± 1.51*
1926	48 725	*18.76 ± 1.51*	265	*30.19 ± 2.09*	50 742	*8.89 ± .87*	316	*31.96 ± 2.03*	98 1467	*13.77 ± .94*	581	*31.15 ± 1.46*
Total or Average 1922-26			**172 1163**	*34.48 ± 3.54*			**248 1777**	*31.74 ± 2.94*			**420 2940**	*32.82 ± 2.97*
Total or Average 1923-26	**128 2103**	*15.50 ± 2.26*	**821**	*33.13 ± 4.43*	**205 3538**	*8.88 ± .69*	**1467**	*33.27 ± 3.45*	**333 5641**	*11.35 ± 1.23*	**2288**	*33.22 ± 3.70*

Data presented in table 1 would appear to indicate first, that mortality rate in chicks from pullet mothers tends to be somewhat greater than in chicks from hen mothers. The probability exists that the nutrient supply in the hen's egg may be somewhat greater than in the pullet's egg because of larger size and less intense production. Second, that there is no consistent or significant difference in the vigor of laying pullets hatched from hen mothers over those hatched from pullet mothers.

2. *Hatchability of Mothers in Relation to Vigor of Daughters.*

Hatchability is measured over a period of eight weeks from March 25 to May 15 each year. The percentage of fertile eggs hatched is used as the hatchability index in each individual pullet or hen.

Egg weight is not a factor in hatchability according to Stewart and Atwood (1909), Dunn (1922), Halbersleben and Mussehl (1922), Jull (1925), Hays and Sumbardo (1927) and others; but the weight of chicks at hatching is intimately correlated with egg weight according to Halbersleben and Mussehl (1922, loc. cit.), Jull (1925 loc. cit.) and others.

Hatchability furnishes a measure of embryonic vigor but there are no published data on the relation of hatchability in families and mortality rate after surviving daughters are placed in the laying houses. Stewart and Atwood (1909) do, however, present data on the mortality rate in chicks to three weeks of age from pullet mothers and from hen mothers. These workers give mortality rate to three weeks on 840 chicks from hens and 591 chicks from pullets of the White Leghorn breed. Mortality rates given are 5 per cent and 14.5 per cent, respectively. Dunn (1922a) has shown that hatching power and mortality rate in chicks to three weeks of age are independent. His data were collected on White Leghorn pullets and hens. The mortality rate for the first three weeks was about 13 per cent of all chicks.

Table 2 shows that the mean percentage of fertile eggs hatched is slightly greater from hen mothers than from pullet mothers on each of the five years reported. The differences are not great but are probably statistically significant. The range of variability by years is also greater in the pullet group with a standard deviation of ±3.98 compared with ±1.68 for the hens.

The mean hatchability of the 248 hens is 76.43±.51 per cent. The mean hatchability of the 172 pullets is 70.78±1.20 per cent. The difference in means amounts to 5.65±1.3. This difference is four times as great as its probable error, which means that hens give higher hatchability than pullets in the flock studied.

Mortality rates in the laying houses are the same as reported in table 1. Pullet mothers show greater variability of losses in daughters in the laying houses than do hen mothers. The years 1923 and 1925 mark the lowest mortality rate in the laying houses and on these two years the average hatchability was highest of the period reported. The year 1924 gave the lowest mean hatchability and by far the greatest mortality in the laying houses. In 1926 many of the embryos of the first four hatches died about the tenth day apparently because of lethal effects of a 2 per cent coal tar disinfectant in which the eggs were dipped before being incubated. It may be possible that the survivors of this treatment were a superior lot which would reduce mortality in the laying houses to some extent. In general, the data on the relation of hatchability to mortality in the laying houses offer slight evidence that high hatchability is associated with superior vigor.

Table 2—Relation of Hatchability to Vigor

Hatching Year	Pullet Mothers			Hen Mothers			Total Mothers		
	Number of Mothers	Average Hatch-ability	*Mortality of Daughters in Laying House Per cent*	Number of Mothers	Average Hatch-ability	*Mortality of Daughters in Laying House Per cent*	Number of Mothers	Average Hatch-ability	*Mortality of Daughters in Laying House Per cent*
1922	44	72.05	*37.72 ± 2.12*	43	77.74	*24.54 ± 1.96*	87	74.86	*31.44 ± 1.50*
1923	30	73.60	*25.00 ± 3.28*	43	75.74	*27.10 ± 1.98*	73	74.86	*26.35 ± 1.56*
1924	22	64.05	*56.96 ± 3.40*	55	73.47	*49.76 ± 2.13*	77	70.78	*51.76 ± 1.81*
1925	28	75.11	*26.34 ± 2.78*	57	77.82	*22.97 ± 1.79*	85	76.93	*23.99 ± 1.51*
1926	48	68.42*	*30.19 ± 2.09*	50	77.56*	*31.96 ± 2.03*	98	73.08*	*31.15 ± 1.46*
Total or Average	**172**	**70.78 ± 1.20**	*34.48 ± 3.54*	**248**	**76.43 ± .51**	*31.74 ± 2.94*	**420**	**74.12 ± .62**	*32.82 ± 2.97*

*Only the last four hatches, the eggs of which were not disinfected, are included here.

3. *Mortality to Eight Weeks in Relation to Mortality in the Laying Houses.*

If vigor is a complex inherited trait, it is conceivable that families of sisters should exhibit a greater degree of uniformity in vigor than the flock as a whole. The probability exists also that the mortality rate in a family for the first eight weeks might give a clue to the probable mortality rate in that family after the surviving daughters are placed in the laying houses. There is an element of unfairness in this comparison in that more daughters from families with low chick mortality will actually be placed in the laying houses giving this group something of a handicap over the high mortality group because larger numbers are subjected to the severe test of heavy egg laying. Table 1 furnishes data on these important questions.

Mortality rate in chicks shows an upward trend from 1923 to 1925 with records for 1926 not significantly different from those of 1925. Losses in the laying houses for 1924 are excessive due to a severe epidemic of roup and are of little value for this study. The most striking fact illustrated by the table is that 1925 shows the highest chick mortality and the lowest mortality in the laying houses. Such a condition appears to be due to chance circumstances alone, however, because 1923 gave the smallest chick mortality and a laying house mortality not significantly different from that of 1925. Table 1 indicates an upward trend in chick mortality but it does not show any relation between chick mortality to eight weeks and subsequent mortality in the same families after placement in the laying houses. The records indicate also that no change has taken place in mortality rate in the laying houses in five years.

4. *Hatching Date in Relation to Mortality.*

Observation and opinion rather generally agree that mortality rate in early hatched chicks is lower than in late hatched chicks. There is no conceivable biological reason why this should be true. If such a difference actually exists, two possible explanations seem pertinent. In the first place, there may be selective mortality in embryos from the early hatches because the embryonic death rate is highest in the early set eggs. In the second place, early hatched chicks receive much closer attention when brooded artificially because weather conditions may be severe and because the caretaker has fewer chicks to occupy his time.

The very great importance of low mortality rate in the laying houses cannot be over-emphasized in production-bred flocks. Early hatching is in rather general favor, hence the value of knowing the relation of time of hatching to vigor.

Table 3 presents the mortality rate in chicks to eight weeks of age, from 1923 to 1926, and the mortality rate of pullets in the laying houses, from 1922 to 1926. These records are given by hatches, the dates being constant from year to year, beginning March 25 and following at weekly intervals to about May 15.

On chart 1 the mean mortality rates to eight weeks by hatches for each year and for the entire four years are presented graphically. This chart shows that the mortality rate in chicks increases consistently with time of hatching for the first three hatches of March 25, April 1 and April 8. In 1923, 1924 and 1926 a distinct decrease in mortality rate is shown for the fourth hatch of April 15. When all chicks are considered over the four-year

Table 3—Relation of Hatching Date to Mortality Rate

Hatching Period	Pullet Mothers				Hen Mothers				Total Mothers			
	Number of Chicks	*Mortality to 8 Weeks Per cent*	Number of Pullets Housed	*Mortality in Laying House Per cent*	Number of Chicks	*Mortality to 8 Weeks Per cent*	Number of Pullets Housed	*Mortality in Laying House Per cent*	Number of Chicks	*Mortality to 8 Weeks Per cent*	Number of Pullets Housed	*Mortality in Laying House Per cent*
1	183	*6.56*	133	*39.10*	396	*5.56*	225	*25.33*	579	*5.87*	358	*30.45*
2	178	*5.62*	123	*29.27*	296	*6.76*	176	*22.73*	474	*6.33*	299	*34.11*
3	165	*13.33*	106	*35.85*	367	*9.54*	193	*26.42*	532	*10.71*	299	*29.77*
4	265	*6.04*	164	*34.15*	413	*7.75*	205	*32.20*	678	*7.08*	369	*33.06*
5	340	*18.24*	167	*29.94*	530	*7.74*	262	*38.55*	870	*11.84*	429	*35.20*
6	323	*17.96*	166	*37.95*	533	*9.19*	257	*37.35*	856	*12.50*	423	*37.59*
7	350	*22.29*	166	*40.36*	488	*9.43*	220	*35.91*	838	*14.80*	386	*37.82*
8	299	*22.74*	138	*28.26*	515	*13.40*	239	*30.96*	814	*16.83*	377	*29.97*

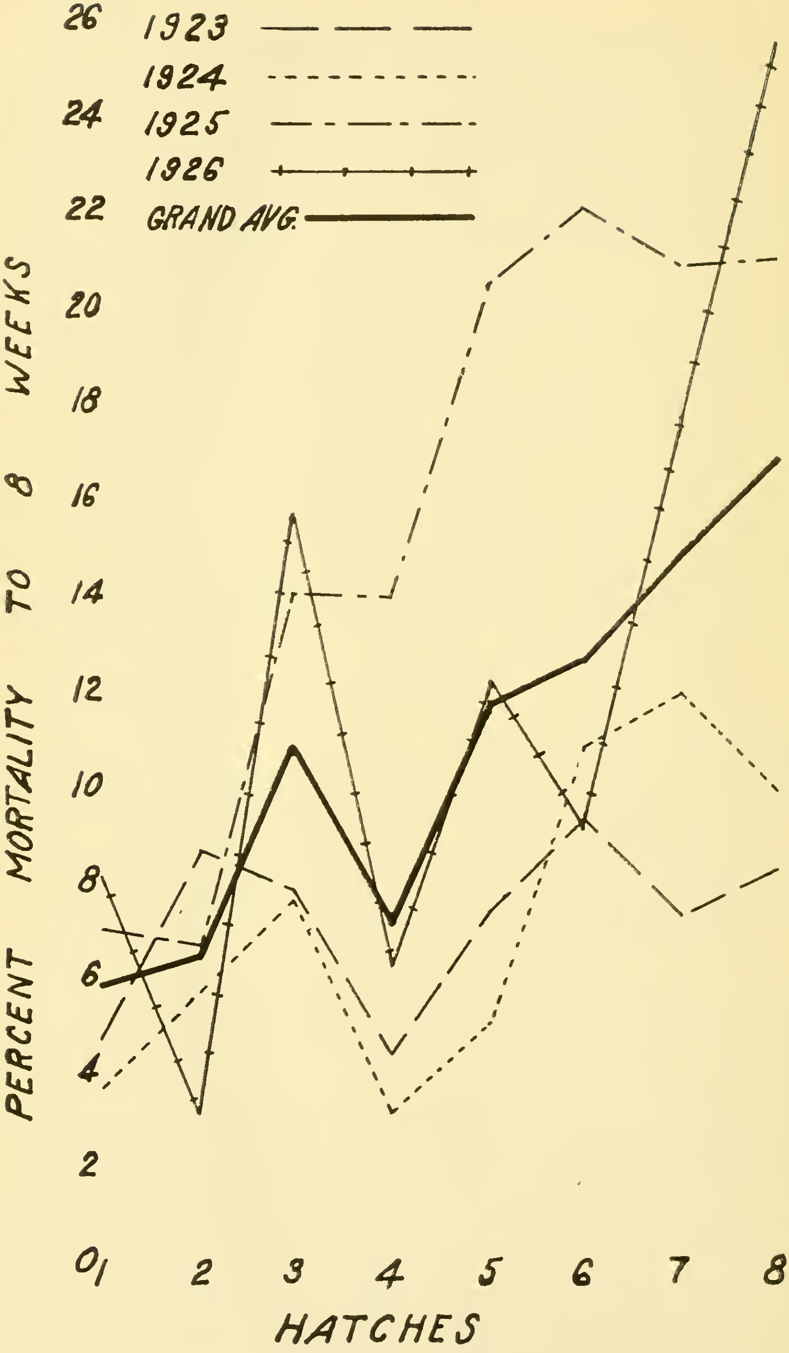


Chart I. Mortality to eight weeks—all mothers.

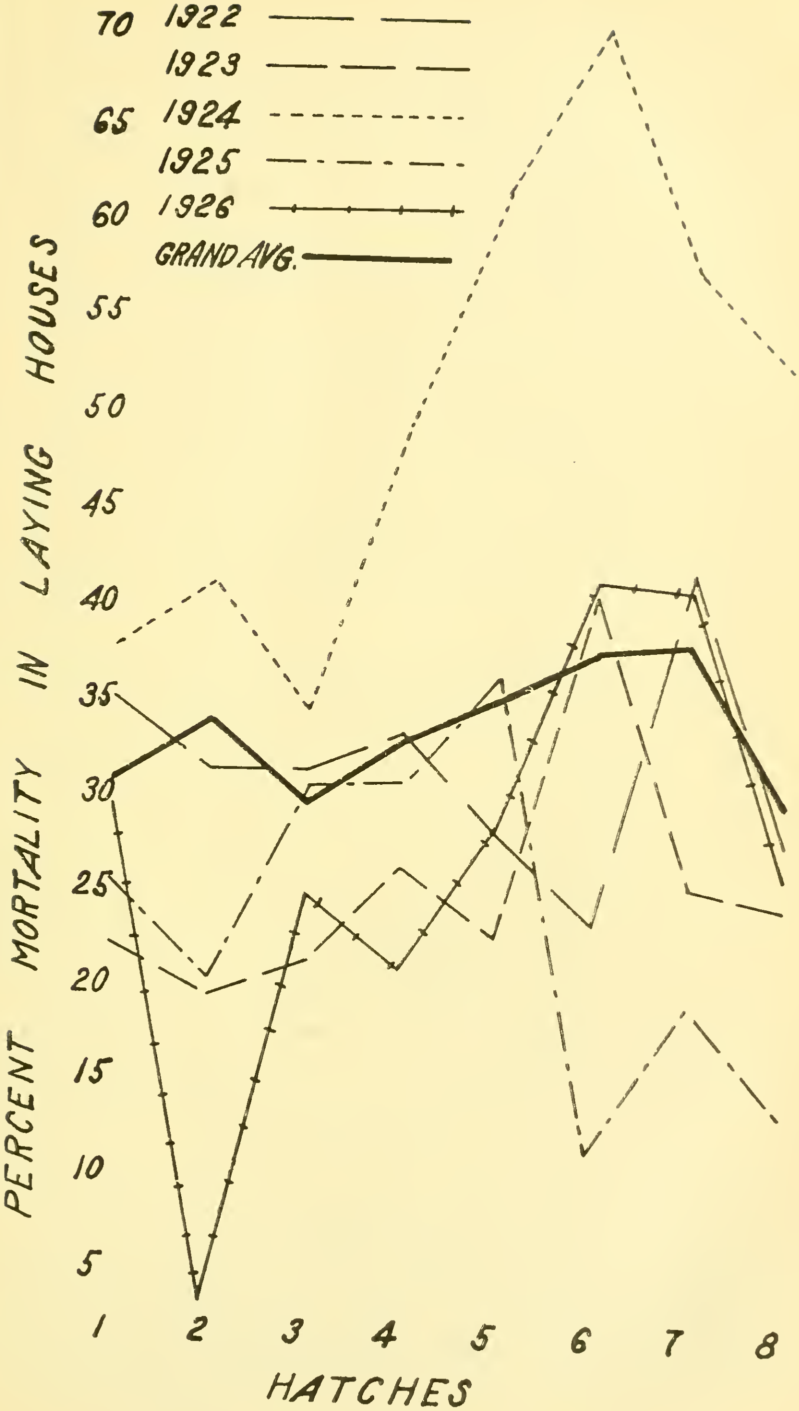


Chart II. Mortality in laying houses—all mothers.

Table 4—Relation of Age at First Egg to Vigor

Hatching Year	Pullet Mothers			Hen Mothers			Total Mothers		
	Number of Pullets	Average Age at First Egg Days	*Mortality in Laying House Per cent*	Number of Pullets	Average Age at First Egg Days	*Mortality in Laying House Per cent*	Number of Pullets	Average Age at First Egg Days	*Mortality in Laying House Per cent*
1922	325	198.54	*37.72 ± 2.12*	301	197.66	*24.52 ± 1.96*	626	198.12	*31.44 ± 1.50*
1923	203	209.07	*25.00 ± 3.28*	291	215.79	*27.10 ± 1.98*	494	213.03	*26.25 ± 1.56*
1924	149	192.21	*56.96 ± 3.40*	399	201.25	*49.76 ± 2.13*	548	198.79	*51.76 ± 1.81*
1925	183	196.92	*26.34 ± 2.78*	427	192.31	*22.97 ± 1.79*	610	193.69	*23.99 ± 1.51*
1926	250	200.30	*30.19 ± 2.09*	306	198.21	*31.96 ± 2.03*	556	199.15	*31.15 ± 1.46*
Total or Average	**1110**	**199.75**	*34.48 ± 3.54*	**1724**	**200.32**	*31.74 ± 2.94*	**2834**	**200.10**	*32.82 ± 2.97*

period, the decrease in mortality rate of the fourth hatch brings their rate very near to that of the first two hatches. No explanation of this apparent inconsistency can be offered at this time.

Considering the period as a whole there is a distinct increase in death rate of chicks as the hatching date advances. Extensive data on these flocks show that hatchability increases as the season advances. This increasing hatching power is clearly not accompanied by increase of vigor as measured by death rate in chicks up to eight weeks of age.

When the relation of date of hatching to mortality rate in the laying houses, as recorded graphically in chart 2, is considered, no significant relation between the two is observed. The data for 1923 show a slight increase in mortality rates for pullets from succeeding hatches. Records for 1924 give a rather distinct increase in mortality rates for later hatches. In 1925 mortality rate goes down in the later hatches. In 1926 there is something of an upward trend in mortality with the later hatching dates.

The grand total line marks the relation of hatching date to mortality rate in the laying houses for the entire five-year period. This line has no significant slope and indicates no relation between time of hatching between March 25 and May 15 and mortality rate for pullets in the laying houses. There is a suggestion in these data that mortality to eight weeks operates on a selective basis eliminating less vigorous chicks in each family so that the survivors in each family exhibit about the same death rate in the laying houses.

5. *Relation of Age at First Egg to Mortality in the Laying Houses.*

The question whether or not breeding for very early sexual maturity reduces vigor is a very pertinent one. This being the case, a study of large numbers of fowls in the same flock over a period of years should furnish some information.

When the mean age at first egg is considered on respective years, no significant change in age has occurred in the five-year period. The standard deviation in age for these flocks amounts to 31.28 days (Hays and Sanborn, 1926b) and is influenced both by heredity and by environment. In all probability the major portion of age differences in table 4 are caused by numerous environmental influences. Both hen mothers and pullet mothers gave the same mean age at first egg for their daughters each year.

Eliminating the obviously abnormal year 1924, there has been no significant change in mortality rate in the laying houses in five years. Since variations in age at first egg are not accompanied by parallel changes in mortality rate in the five-year period studied, these data indicate that age at first egg is not a vigor trait in pullets.

6. *Relation of Genetic Early Maturity to Mortality Rate in the Laying Houses.*

Hays (1924) has shown that Rhode Island Red pullets which begin to lay at 215 days or younger are early maturing by inheritance and that those pullets starting to lay at a greater age than 215 days are genetically late maturing. In order to discover whether or not genetic early maturity is accompanied by low vigor as indicated by death rate in the laying houses, all the pullets used in these studies are classified for maturity. Table 5 gives the complete data:

Table 5—Relation of Genetic Early Maturity to Vigor

Hatching Year	Late Maturity—age over 215 days			Early Maturity—age below 216 days		
	Number of Pullets reaching Maturity	Pullets that died after reaching Maturity		Number of Pullets reaching Maturity	Pullets that died after reaching Maturity	
		Number	*Per cent*		Number	*Per cent*
1922	123	42	*34.15*	505	142	*28.12*
1923	177	37	*20.90*	315	74	*23.49*
1924	115	53	*46.09*	433	222	*51.27*
1925	81	24	*29.63*	528	120	*22.73*
1926	119	28	*23.53*	439	132	*30.07*
Total or Average	**615**	**184**	*29.92*	**2220**	**690**	*31.08*

The proportion of genetically early-maturing pullets is highest in 1925, lowest in 1923 and equal in 1922, 1924 and 1926. The table indicates no relation between heritable early maturity by years and mortality rate. The total mortality in the early-maturing pullets is 31.08 per cent and the total in late-maturing group is 29.92 per cent. These data indicate that genetic early maturity is unrelated to vigor.

7. *Weight at first Egg in Relation to Mortality Rate in the Laying Houses.*

Body weight represents a gross composite of size and is a useful practical measure of rate of food metabolism as well as of meat value. It is important and desirable to know if body weight may be employed as a crude measure of vigor because it is subject to wide variation even when taken for a flock of fowls of uniform age. Hays and Sanborn (1926, loc. cit.) have already shown the standard deviation in weight for this flock of birds to be ±.75 pound when weights were taken at first pullet egg. Hays, Sanborn and James (1924) found the standard deviation in weight for this strain to be ±.54 pound when weights were taken at 150 days. That body weight offers a possibility for selection purposes is apparent, but can it be made use of in selecting for vigor?

No difference in mean weight at first egg is shown between the daughters of hens and of pullets on any year studied, and the mean weight of daughters from all pullet mothers is 5.46 pounds and from hen mothers, 5.43 pounds. Therefore, age of mothers at breeding time does not affect the weight of daughters when they come into sexual maturity.

Table 6 gives the mean weight at first egg for the 1923 flock as 5.6 pounds which is about .2 pounds above the mean for five years. This greater weight in 1923 is probably due to the fact that the pullets averaged nine days older at first egg than the mean for the five years given in table 4. Taking the five-year period as a whole, there is no significant change in weight at first egg.

Table 6—Relation of Weight at First Egg to Vigor

Hatching Year	Pullet Mothers			Hen Mothers			Total Mothers		
	Number of Pullets	Average Weight at First Egg	*Mortality in Laying House Per cent*	Number of Pullets	Average Weight at First Egg	*Mortality in Laying House Per cent*	Number of Pullets	Average Weight at First Egg	*Mortality in Laying House Per cent*
1922	321	5.45	*37.72 ± 2.12*	299	5.35	*24.52 ± 1.96*	620	5.40	*31.44 ± 1.50*
1923	198	5.56	*25.00 ± 3.28*	283	5.61	*27.10 ± 1.98*	481	5.59	*26.25 ± 1.56*
1924	148	5.38	*56.96 ± 3.40*	393	5.56	*49.76 ± 2.13*	541	5.51	*51.76 ± 1.81*
1925	181	5.41	*26.34 ± 2.78*	425	5.35	*22.97 ± 1.78*	606	5.37	*23.99 ± 1.51*
1926	251	5.47	*30.19 ± 2.09*	304	5.27	*31.96 ± 2.03*	555	5.36	*31.15 ± 1.46*
Total or Average	**1099**	**5.46**	*34.48 ± 3.54*	**1704**	**5.43**	*31.74 ± 2.94*	**2803**	**5.44**	*32.82 ± 2.97*

A comparison of the relation between weight at first egg and mortality rate in the laying houses leads to the deduction that the two are independent, because changes in weight at first egg are not accompanied by changes in mortality rate.

8. Relation of Winter Pause to Mortality Rate in the Laying Houses.

The individual egg records for the period from 1922 to 1926 have been gone over and all pullets that stopped laying for four days or more between November first and March first are classed as "pause" birds. Thus the population is divided into the two general classes, pause and non-pause.

Possibly the ability to lay continuously after November first is an indication of high vigor and, conversely, the presence of winter pause may indicate lack of vigor. With the measure of vigor made use of, namely, mortality rate in the laying houses, some information concerning the relation of winter pause to vigor may be obtained.

Table 7—Relation of Winter Pause to Vigor

Hatching Year	Pause			Non-Pause		
	Pullets in Laying House March 1	Pullets dying after March 1		Pullets in Laying House March 1	Pullets dying after March 1	
		Number	*Per cent*		Number	*Per cent*
1922	395	102	*25.82*	198	52	*26.26*
1923	368	77	*20.92*	99	16	*16.16*
1924	309	136	*44.01*	147	54	*36.73*
1925	440	65	*14.77*	103	20	*19.42*
1926	353	87	*24.65*	143	24	*16.78*
Total or Average	**1865**	**467**	*25.04*	**690**	**166**	*24.06*

Table 7 shows that the proportion of non-pause to pause birds is about 1 to 2.7, yet the mean mortality rates in the laying houses for the groups are identical. Records for the five years show no significant differences in mortality rates. Furthermore, there is no significant change in five years in the ratio of non-pause to pause pullets. Therefore, table 7 does not indicate any relation between winter pause and vigor.

9. Relation of Mean Winter Clutch Size to Mortality Rate in the Laying Houses.

Is high rate of laying associated with high mortality rate? The importance of high intensity is widely recognized in production-bred flocks; therefore, it is desirable to know if this high rate of laying is in part responsible for great mortality in heavy laying strains.

Satisfactory measures of intensity are difficult to obtain, but the use of mean winter clutch size as proposed by Hays and Sanborn (1927) offers the advantages of being specific and not obscured by the element of time or by the winter pause. Clutch size is also inherited in Mendelian fashion as reported in the above publication. Birds carrying both dominant factors for large clutch size will have a mean winter clutch greater than 2.6, those lacking one factor will show a clutch size between 2.2 and 2.6, while birds lacking both factors will have a clutch size not far from 2.0. In these studies the pullets have been divided into two classes: Those carrying both factors for large clutch and those carrying none or only one factor for large clutch.

Table 8—Relation of Intensity to Vigor

	High Intensity—Clutch over 2.6			Low Intensity—Clutch under 2.6		
Hatching Year	Pullets in Laying House March 1	Pullets dying after March 1		Pullets in Laying House March 1	Pullets dying after March 1	
		Number	*Per cent*		Number	*Per cent*
1922	249	66	*26.51*	328	82	*25.00*
1923	141	28	*19.86*	295	48	*16.27*
1924	183	71	*38.80*	268	112	*41.79*
1925	318	46	*14.47*	221	38	*17.19*
1926	217	37	*17.05*	279	75	*26.88*
Total or Average	**1108**	**248**	*22.38*	**1391**	**355**	*25.52*

In table 8 the proportion of high intensity pullets to those of low intensity varies from year to year, yet the differences in mortality rate for the two classes is not great. The smallest proportion of high intensity birds occurred in the 1923 flock while the greatest proportion appeared in the 1925 flock. On these two years the mortality rates were lowest of the five-year period. This fact, together with the close agreement in total mortality rates for both high and low intensity groups, would seem to indicate that intensity of production is independent of vigor as measured by losses in the laying houses.

10. The Relation of Broodiness to Mortality Rate in the Laying Houses.

The broody trait is a recognized undesirable trait from the standpoint of high fecundity. Hence, in order to raise the mean egg production of a flock to a high level, the percentage of birds going broody the first laying year must be greatly reduced from what might be considered normal in the general purpose breeds.

In the Massachusetts Agricultural Experiment Station flock of Rhode Island Reds the percentage of birds going broody their first laying year was 90 for the flock of 1913 and for the flock of 1926 the figure was 10. In this time interval the number of broody periods has fallen from more than five to less than two. There has not been a significant reduction in the mean length of broody periods, however. (Hays and Sanborn 1926a).

These studies were undertaken to discover if the elimination of the broody trait has been inimical to vigor. A total of 2163 birds hatched in the five years from 1922 to 1926 have been classified as broody or non-broody. Since the greatest percentage of pullets tend to become broody before July 1, it has been decided to use pullet records up to July 1 for the classification. Those pullets that actually went broody before July 1 each year are placed in the broody class and all others in the non-broody class. Such classification is faulty in that many birds actually do not show broody behavior by July 1 and a smaller proportion not until later laying years. For this study such crude classification should be of some value.

Table 9—Relation of Broodiness to Vigor

Hatching Year	Broody			Non-Broody		
	Pullets in Laying House July 1	Pullets dying after July 1		Pullets in Laying House July 1	Pullets dying after July 1	
		Number	*Per cent*		Number	*Per cent*
1922	148	12	*8.11*	347	41	*11.82*
1923	106	4	*3.77*	314	32	*10.19*
1924	126	11	*8.73*	171	13	*7.60*
1925	210	7	*3.33*	286	21	*7.34*
1926	104	2	*1.92*	351	53	*15.01*
Total or Average	**694**	**36**	*5.19*	**1469**	**160**	*10.89*

Table 9 shows the percentage of birds not going broody before July 1 to be as follows: 1922, 70 per cent; 1923, 75 per cent; 1924, 58 per cent; 1925, 58 per cent; and 1926, 77 per cent. The records for 1924 are valueless because of a severe roup epidemic, but the records for 1925 show that the increase in broodiness up to July 1 was associated with the lowest mortality rate in the laying houses for a five-year period.

Table 9 also indicates a consistent and almost parallel decline in mortality rate for both broodies and non-broodies up to 1925. The records for 1926 assign a mortality rate after July 1 of 1.92 per cent for broody birds and 15.10 per cent for non-broody birds. This very abrupt increase in mortality in the non-broody group cannot be considered normal and cannot be explained. The mortality rate in the non-broody group is greater than for the broody group in the four normal years reported.

The total mortality rate for five years is 5.19 per cent in the broody group and 10.89 per cent in the non-broody group. If records for the epidemic year 1924 are omitted, the mortality rate for broody birds is 4.42 per cent, and for non-broody birds 11.33 per cent. Omitting 1926, the broody group show a mortality of 5.76 per cent and the non-broody group 9.57 per cent. These data indicate that the manifestation of broody behavior before July 1 of the pullet laying year is an indication of superior vigor and that the elimination of the broody trait in this flock has been accompanied by greater mortality rate in the laying houses.

11. Relation of Persistency in Laying to Mortality Rate in the Laying Houses.

High persistency in laying is an important and desirable trait from the standpoint of fecundity. In ordinary poultry practice the date of onset of complete molt is made use of as an indicator of persistency. The importance of late molting as a desirable fecundity trait has been recognized for several decades and is constantly made use of in culling operations. Persistency behaves in Mendelian fashion in inheritance and high persistency is linked with early sexual maturity (Hays, 1927).

The dividing line between genetically low and genetically high persistency appears to come at about 315 days. Birds have therefore been classed as high in persistency if they continue to lay for 315 days or more from the time of first pullet egg and low in persistency if they lay for a shorter period than 315 days. In order to classify the families of sisters used in these studies it has been necessary to obtain the mean persistency of the surviving daughters of each family. If this mean family persistency falls below 315 days the entire group of sisters is classed as low in persistency even though some individuals may actually lay for 315 days or longer. This method is at best only an approximate separation of the population into high and low persistency classes.

In studying the relation of persistency to vigor as measured by mortality rates in the laying houses under such a classification as is made in table 10, the assumption must be that surviving sisters in each family represent a true sample of all the sisters of the family with regard to persistency. Actual persistency records can only be secured on surviving sisters and their records must be used to classify all sisters.

Table 10—Relation of Persistency to Vigor

Hatching Year	Families of Low Persistency—below 315 days				Families of High Persistency—above 314 days			
	Number of Families	Number of Pullets put into Laying House	Pullets dying		Number of Families	Number of Pullets put into Laying House	Pullets dying	
			Number	*Per cent*			Number	*Per cent*
1922	17	105	31	*29.52*	67	538	168	*31.23*
1923	29	198	48	*24.24*	40	316	85	*26.90*
1924	22	159	79	*49.69*	46	375	188	*50.13*
1925	24	167	41	*24.55*	59	448	106	*23.66*
1926	28	161	54	*33.54*	65	402	116	*28.86*
Total or Average	**120**	**790**	**253**	*32.03*	**277**	**2079**	**663**	*31.89*

Reference to table 10 brings out the fact that no important change has taken place in five years in the percentage of genetically highly persistent birds. When the percentage of high birds is calculated by families the figures are practically identical with figures based on the number of individual birds. The greatest proportion of high persistency birds occurred in the 1922 flock, and the smallest percentage in the 1923 flock. The years 1924 and 1926 show practically a constant proportion of high and low persistency females.

No relation is apparent between high persistency and mortality rate. In the five-year period 2869 birds are considered, about 73 per cent of which are highly persistent. The total mortality rate for the persistent pullets is 31.89 per cent, and for the low persistent group the figure is 32.03 per cent. Therefore no difference in vigor between the groups is apparent, and persistency and vigor are independent.

12. *Relation of Winter Egg Production to Mortality Rates in the Laying Houses.*

Harris (1926 and 1927) has shown that the egg production of birds dying during their pullet year is lower than production for the same time interval by birds that survive to the end of the year. His records were obtained on White Leghorns, Rhode Island Reds and White Wyandottes in the Storrs Egg Laying Contests. Harris also found that the egg records of birds that died were more variable month by month, indicating that both good and inferior layers were concerned. This worker concluded from his studies that lower mean monthly production tended to be associated with lower vigor, and that the relation between egg production and mortality rate is definite but probably highly complex.

The pullets hatched during the five years covered by these studies are tabulated to discover whether heavy laying affects mortality in this strain. Only pullets surviving to March first are considered. The individual egg records to March first of all pullets dying between March first and the close of the pullet laying year are grouped together, and the individual egg records to March first for all pullets living to the close of the year are placed in another group. In this manner it is possible to discover relations between winter egg production and subsequent rates.

Table 11—Relation of Winter Egg Production to Vigor

Hatching Year	Pullets Dying after March 1			Pullets Living Throughout Year	
	Number of Pullets	Mean winter egg production	Mortality after March 1 *Per cent*	Number of Pullets	Mean winter egg production
1922	154	67.90 ± 1.86	*26.06 ± 1.51*	437	67.08 ± 1.33
1923	84	47.63 ± 2.09	*18.58 ± 1.69*	368	51.66 ± 1.41
1924	217	64.55 ± 1.27	*44.47 ± 1.87*	271	67.93 ± 1.68
1925	91	71.45 ± 2.12	*16.40 ± 1.14*	464	71.44 ± 1.42
1926	115	54.86 ± 1.67	*22.82 ± 1.29*	389	61.37 ± 1.14
Total or Average	**661**	**62.44 ± 2.67**	*25.52 ± 3.01*	**1929**	**64.16 ± 2.08**

Table 11 confirms Harris's (1927 loc. cit.) observations that pullets which die during their laying year show a greater variability in egg production previous to death than is shown for the same period by pullets which survive the year. This fact is illustrated by the greater magnitude of the probable error in mean winter production for the group dying after March 1.

These data do not indicate, however, that mean egg production from first egg to March first is lower in the group of birds that subsequently die before the end of the pullet laying year. Neither do the data indicate that heavy winter laying is responsible for later mortality, because the group which died and the group which lived have almost identical mean winter production records. Mean winter records for the two groups for the five year period are 62.44±2.67 eggs for the group dying after March 1, and 64.16±2.08 eggs for the group surviving the year. These means are statistically identical and point to no relation between winter egg production and subsequent mortality rate in this strain of birds. High winter egg record cannot therefore be used as a measure of vigor and it cannot be held responsible for high mortality in the laying houses during the summer months.

13. General Classification of Causes of Mortality in Laying Houses.

Many difficulties are encountered in attempting to discover causes of death in domestic fowl. Even when careful post-mortem examinations are made on every fowl, there are many specimens which show no specific cause. In the stock of the Massachusetts Agricultural Experiment Station post-mortem examinations have only been possible in a limited way and the majority of recorded causes of death are based on external observations only. These records are thus presented not for their scientific value but to give a general insight into the relative frequency of types of disorders encountered during the experiment.

Table 12 indicates no significant differences in the percentage of deaths in the laying houses between the daughters of pullet mothers and hen mothers. The percentage of losses from the same causes varies from year to year. For example, cannibalism made its greatest inroads in 1922 and 1923. Since those years losses from cannibalism have decreased, reaching an insignificant figure in 1926. The general depleted condition, "going light", characterized by excessive loss of weight and strength has increased during the five-year period causing 42 per cent of all losses in 1926. Paralysis has not been a very important cause of losses in the flocks. The heaviest losses from this disease occurred in 1926. Roup of the diphtheritic type caused heavy losses in 1924 and 1925. This disease has not materially affected losses on the other three years. Miscellaneous unclassified causes of death have been important each year. Such losses have not varied greatly from 35 per cent of the total. These causes are not of epidemic nature and might be credited to low vitality.

The general summary for the entire period shows cannibalism as responsible for slightly more than 20 per cent of the losses. This habit has been corrected by methods of management and is no longer an important cause of losses. The depleted condition, "going light," has not been attributed to any specific diseases or to internal or external parasites. It is apparently due to faulty metabolism and other obscure causes. This disorder shows an upward tendency, and no method of control is known. Paralysis appears to depend largely upon sanitation for control, and requires careful watching because it seems to be increasing slightly. Roup is a very serious epidemic disease and

Table 12—General Causes of Deaths of Pullets in the Laying Houses

Deaths by Hatching Years	Pullet Mothers					Hen Mothers					Total Mothers				
	Cannibalism	Going Light	Paralysis	Roup	Other Causes	Cannibalism	Going Light	Paralysis	Roup	Other Causes	Cannibalism	Going Light	Paralysis	Roup	Other Causes
1922:															
Number	64	4	3	2	56	38	4	1	1	32	102	8	4	3	88
Per cent	*49.61*	*3.10*	*2.33*	*1.55*	*43.41*	*50.00*	*5.26*	*1.32*	*1.32*	*42.11*	*49.76*	*3.90*	*1.95*	*1.46*	*42.93*
1923:															
Number	14	15	4	1	19	20	24	7	0	33	34	39	11	1	52
Per cent	*26.42*	*28.30*	*7.55*	*1.89*	*35.85*	*23.81*	*28.57*	*8.33*	*0*	*39.29*	*24.82*	*28.47*	*8.03*	*.73*	*37.96*
1924:															
Number	8	10	2	53	17	20	18	7	118	41	28	28	9	171	58
Per cent	*8.89*	*11.11*	*2.22*	*58.89*	*18.89*	*9.80*	*8.82*	*3.43*	*57.84*	*20.10*	*9.52*	*9.52*	*3.06*	*58.16*	*19.73*
1925:															
Number	7	5	1	8	28	25	17	1	20	36	32	22	2	28	64
Per cent	*14.29*	*10.20*	*2.04*	*16.33*	*57.14*	*25.25*	*17.17*	*1.01*	*20.20*	*36.36*	*21.62*	*14.86*	*1.35*	*18.92*	*43.24*
1926:															
Number	2	31	9	3	35	1	45	10	4	41	3	76	19	7	76
Per cent	*2.50*	*38.75*	*11.25*	*3.75*	*43.75*	*.99*	*44.55*	*9.90*	*3.96*	*40.59*	*1.66*	*41.99*	*10.50*	*3.87*	*41.99*
Total:															
Number	**95**	**65**	**19**	**67**	**115**	**104**	**108**	**26**	**143**	**183**	**199**	**173**	**45**	**210**	**338**
Per cent	*23.69*	*16.21*	*4.74*	*16.71*	*38.65*	*18.44*	*19.15*	*4.61*	*25.35*	*32.45*	*20.62*	*17.93*	*4.66*	*21.76*	*35.03*

has been responsible for about 22 per cent of all losses. During the last two years reported it was controlled by vaccination with a bacterin. Thirty-five per cent of all losses in the five-year period are due to unclassified causes. These losses have not varied widely throughout the period reported. Reduction of these losses will depend largely upon the use of highly vigorous stock, strict sanitary methods of management, and more improved methods of feeding aided by recent discoveries.

Changes in Vigor in Families.

The fact should be clearly understood that the chief goal sought for in the breeding operation reported here has been high fecundity. High vigor has been considered, but fecundity has not been sacrificed to maintain vigor. Table 13 is given below to show how vigor of the birds has varied throughout the five-year period reported.

Table 13—Percentage of Families with No Mortality

Hatching Year	To 8 Weeks of Age			In Laying Houses		
	Pullet Mothers	Hen Mothers	Total Mothers	Pullet Mothers	Hen Mothers	Total Mothers
1922	...	...	...	*13.64*	*13.95*	*13.79*
1923	*53.33*	*30.23*	*39.73*	*33.33*	*13.95*	*21.92*
1924	*22.73*	*41.82*	*36.36*	*9.09*	*5.45*	*6.49*
1925	*7.14*	*31.58*	*23.53*	*28.57*	*21.05*	*23.53*
1926	*12.50*	*38.00*	*25.51*	*20.83*	*16.00*	*18.37*
Total families (1922-1926)	**128**	**205**	**333**	**172**	**248**	**420**
Families with no mortality— Number	29	73	102	36	35	71
Per cent	*22.66*	*35.61*	*30.63*	*20.93*	*14.11*	*16.90*

Table 13 indicates a decrease in the percentage of families from pullet mothers that have no loss in chicks to eight weeks of age, between 1923 and 1926. In the same period there has been no significant change in percentage of families from hen mothers with zero mortality to eight weeks of age. When all families are considered year by year, a significant decrease in the proportion of perfect livability families is observed. Hen mothers exhibit a greater proportion of perfect livability families than do pullet mothers for the entire four years covered by these data. The total percentage of perfect livability families from hen mothers is 35.61 and from pullet mothers, 22.66.

When consideration is given to the relative percentages of perfect livability of families in the laying houses, pullet mothers have an upward trend in percentage of perfect livability daughters from 1922 to 1926. In the same period hen mothers also show improvement but to a lesser degree than pullet mothers. In general, the statement may be made that the proportion of high vigor families has increased during the five-year period studied.

Another very significant fact is brought to light in table 13, namely, that the percentage of families of perfect livability in chicks is greater from hen mothers than from pullet mothers but the percentage of perfect livability of daughters in the laying houses is greater from pullet mothers. It seems probable, therefore, that chick mortality removes a greater proportion of low vigor chicks from pullet mothers than from hen mothers. Chicks from hens are probably equipped with a larger supply of food nutrients from the egg than are chicks from pullet mothers and for this reason the weaker individuals may survive longer only to succumb later to the severe strain of heavy egg laying. These data illustrate the method of securing higher vigor by constantly using stock from low mortality families for breeding purposes.

Summary and Conclusion

Mortality in chicks to eight weeks of age is not a reliable index of vigor because it bears little relation to mortality rates in the same families after surviving daughters are placed in the laying houses.

Hen mothers give more vigorous chicks to eight weeks of age than do pullet mothers, but there is not a significant difference in the vigor of pullets from hen mothers over pullet mothers after the pullets are confined to the laying quarters.

Hens showed higher hatchability than pullets, and high hatchability shows something of a tendency to be associated with low mortality in the laying houses. High hatchability may therefore be used as one criterion of superior vigor in resulting offspring.

Late hatching decreases vigor in chicks to some extent, but has no effect on vigor of pullets in the laying houses.

Age at first egg does not affect vigor of pullets.

Genetic early maturity has no relation to vigor of pullets.

Weight at first egg is not a measure of vigor.

Winter pause shows no relation to vigor as measured by mortality rates for pullets in the laying houses.

Intensity of laying does not affect vigor in pullets.

The occurrence of broodiness before July first of the pullet laying year appears to indicate superior vigor in the strain of birds studied. Non-broody birds exhibit a higher mortality rate in the laying houses than do broody birds.

There is no evidence of a relation between persistency and vigor in the data presented.

Winter egg production in low vigor birds is more variable than in those of high vigor, but there is no difference in the number of eggs laid to March first by vigorous and non-vigorous pullets. Winter egg record is not an indication of vigor, and no evidence is available that would indicate that heavy winter laying reduces vigor.

Four of the important heritable characteristics necessary for high egg production are independent of vigor; therefore, fixing early maturity, high intensity, non-pause and high persistency does not decrease vigor. The data presented, however, indicate that eliminating broodiness in Rhode Island Reds may reduce vigor.

The most potent cause of deaths in the laying houses falls in the unclassified group which may be considered lack of vigor. Roup and "going light" are the most important disorders in the flocks studied.

In improving a flock for vigor, the most feasible practice consists in breeding exclusively from those families showing the very lowest mortality of pullets in the laying houses.

References

Bittenbender, H. A. 1922. Breeding Rhode Island Reds for type and egg production. Iowa Agr. Expt. Sta. Bul. 202.

Dryden, J. 1921. Egg-laying characteristics of the hen. Oreg. Agr. Expt. Sta. Bul. 180.

Dunn, L. C. 1922. The relationship between the weight and the hatching quality of eggs. Conn. (Storrs) Agr. Expt. Sta. Bul. 109.

Dunn, L. C. 1922a. Hatchability and chick mortality. Poultry Sci. I. No. 2.

Halbersleben, D. L., and F. E. Mussehl. 1922. Relation of egg weight to chick weight at hatching. Poultry Sci. I. No. 4.

Harris, J. A. 1926. The monthly egg records of birds which die during the first laying year. Poultry Sci. VI. No. 1.

Harris, J. A. 1927. Further studies of the monthly egg records of birds which die during the first laying year. Poultry Sci. VI. No. 5.

Hays, F. A. 1924. Inbreeding the Rhode Island Red fowl with special reference to winter egg production. Amer. Nat. 58:43-59.

Hays, F. A., Ruby Sanborn and L. L. James. 1924. Correlation studies on winter fecundity. Mass. Agr. Expt. Sta. Bul. 220.

Hays, F. A., and Ruby Sanborn. 1926a. Broodiness in relation to fecundity in the domestic fowl. Mass. Agr. Expt. Sta. Tech. Bul. 7.

Hays, F. A., and Ruby Sanborn. 1926b. Annual persistency in relation to winter and annual egg production. Mass. Agr. Expt. Sta. Tech. Bul. 9.

Hays, F. A., and Ruby Sanborn. 1927. Intensity or rate of laying in relation to fecundity. Mass. Agr. Expt. Sta. Tech. Bul. 11.

Hays, F. A., and A. H. Sumbardo. 1927. Physical character of eggs in relation to hatchability. Poultry Sci. VI. No. 4.

Hays, F. A. 1927. The inheritance of persistency and its relation to fecundity. Proc. World's Poultry Congress.

Jull, M. A., and S. Haynes. 1925. Shape and weight of eggs in relation to their hatching quality. Jour. Agr. Research XXXI. No. 7.

Lippincott, W. A. 1921. Poultry production. New York: Lea and Febiger.

Pearl, R. 1911. Breeding poultry for egg production. Maine Agr. Expt. Sta. Bul. 192.

Rice, J. E., and H. E. Botsford. 1925. Practical poultry management. New York: John Wiley & Sons, Inc.

Stewart, J. H., and Horace Atwood. 1909. Some factors influencing the vigor of incubator chickens. W. Va. Agr. Expt. Sta. Bul. 124.

3500—4-'28. No. 2109

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 243 May, 1928

The McIntosh Apple on the New York Market

By Lorian P. Jefferson

As one part of a general study of the consumer demand for apples, an effort was made to determine the status on our largest outside market, of the variety about which the recent upward trend of commercial production of apples in New England has centered.

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AGRICULTURAL EXPERIMENT STATION

AMHERST, MASS.

THE McINTOSH APPLE ON THE NEW YORK MARKET

By Lorian P. Jefferson,

Assistant Research Professor of Agricultural Economics.

The demand for New England apples in markets outside New England is a matter of increasing concern to New England growers. In 1926 there were about 5,900,000 bearing trees with some 2,000,000 not yet in bearing in the orchards of New England. In Massachusetts the non-bearing trees comprised at that time 35 per cent of the total number of trees in the commercial orchards of the state. Obviously this forecasts a considerable increase in the production of apples in New England within a few years. A conservative estimate of the normal increase in the number of bearing trees to be reached by 1940 fixes this at some 600,000 more than there were in 1925; allowing for unfavorable conditions in the apple industry, this figure can hardly be less than 125,000 more trees than were in bearing in 1925.[1]

The extension of better orchard practice is resulting in a larger proportion of marketable apples. In view of the probable increase in the volume of New England apples to be marketed, the growers of Massachusetts are naturally interested in the possible outside markets for New England apples. This study was made in order to determine the demand in New York, the nearest and largest of these markets, particularly for the McIntosh, the variety which interests the growers of the state in general more than any other.

The Outside Demand for New England Apples.

The distribution of New England apples in certain markets outside New England has been reported for a number of years by the United States Department of Agriculture. In the season of 1925-26, these reports showed that but sixteen of the markets included in the reports received apples from New England, and that more than 75 per cent of the total volume (712 cars) was shipped to New York City. None went farther west than Chicago or farther south than Cincinnati.

In the fall of 1927 the markets of Detroit, Mich., Hamilton and London, Ont., Niagara Falls, Buffalo, Rochester and Syracuse, N. Y., were visited in an effort to determine the distribution of New England apples. In Detroit one dealer was found, the oldest in business in the city, who recalled that some twenty-five years ago, two or three cars of New England apples were shipped to Detroit in a season of shortage in the Middle Western crop.

In the other United States markets the story was much the same. Either nobody recalled ever seeing any New England apples in the market, or sometimes a few had been received when the local crop was short.

In the Canadian markets visited no record of receipts of New England apples could be found. Transportation rates and the Canadian crop combine to keep New England apples from these markets.

The crop of 1926 was one of the largest ever grown in the United States, and New England apples were distributed much less widely than in the previous year. This was obviously because prices were too low to warrant the added costs of transportation. One carload was reported in Pittsburgh this season, all the rest going to New York City, which received 445 cars.

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[1] The Apple Situation in New England, published by the Connecticut and Maine Experiment Stations, and the Extension Services of Massachusetts, New Hampshire and Rhode Island, 1927.

In the present season, 1927-28, to March 15, New England is reported to have shipped about 95 per cent of her outside shipments to New York City. The remainder have been distributed as follows:—14 cars to Philadelphia, which has formerly received very few New England apples; 8 cars to Cleveland; 7 cars to Cincinnati; 4 cars to Chicago; 2 cars to Pittsburgh; and 1 car to Washington, D. C.

It is apparent from the government reports that New England apples now and then reach some of these markets in less than carload lots, since prices of New England apples are sometimes quoted when carlots are not reported. This may be accounted for by reshipments from New York or other outside markets.

The comparatively narrow distribution for New England apples in view of the increasing size of the commercial crop indicates a growing appreciation of New England apples in New England markets. This preference for home-grown fruit has been shown also by statements of wholesalers, retailers and consumers. Some wholesalers report an increase in the proportion of New England apples handled. Retailers often state that they sell only New England apples as long as they are available or when they are able to get the quality desired. Many, too, complain that they are not able to get the quality they want, hence they handle Northwestern apples. This is heard more often at fruit stands than in retail stores. The fruit stand sells by the apple instead of by weight or measure, and the customer is more critical of the one apple or perhaps the dozen apples he buys than he is of the peck or bushel. If he buys one apple, he wants it perfect. If he buys a peck, he does not bother to examine each apple.

Many customers are now demanding home-grown apples. In some markets of the state no local apples were formerly to be found—or if there were any they were of such poor quality that they were not desired by the public. In these same markets home-grown apples are now much preferred to apples from other sections.

The Demand for McIntosh in New York City.

In order to determine the demand for New England apples, particularly the McIntosh, in New York City, since that is the largest consuming center outside New England, many wholesalers, brokers and jobbers were interviewed. From these interviews it is evident that no New England variety, except McIntosh, is especially favored in New York. Other varieties, such as Baldwin, Greening, Wealthy and Northern Spy, are received, but the McIntosh is the most popular variety which New England ships to New York. It is consumed largely by the Jewish people of the city. For this there seem to be two main reasons:

1. Many dealers of this race are in the wholesale fruit and vegetable business in New York City. These men have had the chance to become acquainted with this variety and they have recommended it to their Jewish friends among the retailers and consumers. Wholesalers repeatedly made the statement that most of the McIntosh sold in the city were consumed by Jews and that comparatively few consumers of other nationalities know the variety.

2. Some of the dealers said that the Jewish people are very particular as to the quality of foods they use and having learned the fine flavor and texture

of the McIntosh, they buy it for eating purposes in preference to other varieties.

Before the McIntosh became known, the Jewish people of the city regarded the Northern Spy as especially desirable and consumed a large proportion of this variety reaching the New York market. With the introduction of the McIntosh and its longer term in storage each year, the Northern Spy has ceased to be the favorite of the Jews of New York City.

The reports of the New York auction market for the season 1926-27 show that of 263,275 boxes of McIntosh apples sold at auction only 7 per cent were from New England, 3 per cent from New York State and other states of the East and Middle West, 21 per cent from British Columbia, and the remainder (69 per cent) from the Northwestern States. Those from New England did not begin to arrive in New York in quantity till December and shipments ended in March. The shipments from the Northwest continued from September to April inclusive, comprising from 97 per cent to 100 per cent of the monthly sales at auction during the fall months. New York State McIntosh were mostly sold in the last three months of the season, February, March and April. This doubtless represents but a small portion of the total sales of New York McIntosh apples in the city, since the growers and local buyers of the state know this market and its dealers more intimately than shippers from other McIntosh producing areas, and probably send many more apples directly to New York receivers than do shippers in the other sections.

In 1927-28, when the total auction sales were 142,265 bushels, the proportions from the different producing areas had changed somewhat, 7 per cent coming from New England, 8 per cent from New York and the Middle West, nearly 38 per cent from British Columbia, and but 47 per cent from the states of the Northwest. In this season shipments from New England were heaviest in March and April, whereas the receipts from the Northwestern States were heaviest in November and those from British Columbia in December and January.

Table 1 shows the total volumes received at the auction market from the different sections producing McIntosh: From the Northwestern States; from British Columbia; from New York, Pennsylvania, Ohio, Wisconsin and a few

Table 1.—Total Volumes and Average Seasonal Prices of McIntosh from Different Sections Sold at Auction in New York, 1924-1925 to 1927-1928.

1924-25	Northwest	British Columbia	New York and Other	New England	**Total**
Total volume, bu.	26,261	57,531	7,793	....	**91,585**
Average price	$ 2.93	$ 3.02	$ 3.50	....	
1925-26					
Total volume, bu.	12,440	14,775	64,030	27,913	**119,158**
Average price	$ 2.55	$ 3.55	$ 2.63	$ 2.70	
1926-27					
Total volume, bu.	180,670	57,675	7,365	17,565	**263,275**
Average price	$ 2.37	$ 2.79	$ 2.55	$ 2.57	
1927-28					
Total volume, bu.	65,625	53,485	12,560	10,495	**142,265**
Average price	$ 2.89	$ 3.25	$ 2.71	$ 3.41	
Four-Season Average Price	**$ 2.55**	**$ 3.06**	**$ 2.71**	**$ 2.80***	

* Three seasons only.

scattered shipments from other states; and from New England. These figures are given for the four seasons 1924-25 to 1927-28. McIntosh from New England have, however, been sold at auction only during the last three seasons.

A comparison of the auction prices received for McIntosh from these different sections of the country shows that during the seasons from 1924-25 to 1927-28, those from British Columbia have averaged highest, bringing $3.06 a box. New England McIntosh have averaged next highest, $2.80 a box; and in the past season, 1927-28, they have brought the highest average price, $3.41. The McIntosh from Montana and other Northwestern States have averaged $2.55 for the four seasons, and each season except 1927-28 have averaged less than the apples from any other section.

In the accompanying table (Table 2) a comparison is made of the prices

TABLE 2.—Comparative Prices, Grade A McIntosh Sold at New York Auction Market on Equivalent Dates, Seasons 1925-26 to 1927-28.

		Season 1925-26		
Month	New England	New York	Montana	British Columbia
November	$2.96	....	....	$3.07
	2.57	....	....	3.00
	3.31	$2.47	....	....
	....	2.63	$3.19	....
December	2.90	....	....	3.02
	3.17	....	2.70	....
	2.59	....	3.05	....
	3.08	....	2.68	....
	2.78	....	2.46	....
	2.65	2.29	2.27	....
	....	2.59	2.54	....
January	3.59	2.85	2.98	....
	1.50	2.51	....	....
	3.59	2.39	3.04	2.97
	2.36	2.38	....	....
	2.42	....	....	2.42
February	1.40	2.56	....	....
	2.80	2.71	....	....
March	....	3.23	3.55	....
	2.68	2.90	....	....
		Season 1926-27		
September	....	$2.65	$2.79	....
October	$2.30	....	2.08	....
November	....	....	2.36	....
December	2.35	....	3.00	....
	3.17	....	2.62	$2.88
	2.20	2.61	2.97	2.83
	2.77	....	2.19	....
	2.55	....	2.87	....
	2.85	....	3.00	2.53
	2.81	....	2.87	2.98
	2.90	....	2.88	3.18

TABLE 2.—Comparative Prices, Grade A McIntosh Sold at New York Auction Market on Equivalent Dates, Seasons 1925-26 to 1927-28. *Continued.*

Season 1926-27 Continued

Month	New England	New York	Montana	British Columbia
January	2.87	....	2.29	2.50
	2.60	....	2.98	....
	2.89	....	....	2.79
	2.75	....	2.89	2.61
	2.21	....	2.79	2.30
	2.15	....	2.79	2.34
	2.30	....	2.79	2.52
	2.33	2.25	2.44	2.19
	2.64	2.15	2.47	2.42
	2.28	....	2.51	2.41
	2.78	....	2.68	1.74
February	....	3.23	2.19	3.12
	2.15	3.10	2.62	....
	....	2.88	3.11	....
	....	2.76	2.80	....
	....	2.51	3.05	....
	2.85	2.87	3.00	....
March	3.11	....	3.08	3.29
	2.77	3.09	3.88	3.63
	3.09	....	3.66	....
	2.54	....	3.29	3.41
	3.73	....	3.23	3.49
	....	3.45	2.72	3.37
	....	2.03	3.28	3.98
		Season 1927-28		
October	$2.98	....	....	$3.04
	2.80	....	$2.86	3.00
	2.84	....	....	3.01
	....	....	2.73	3.21
November	3.25	....	3.25	....
	2.94	....	2.75	....
December	3.50	....	....	3.39
	3.49	....	....	3.20
January	3.05	....	3.13	3.11
	3.18	....	3.14	3.07
February	3.68	....	3.04	3.33
March	3.58	....	3.48	....
	3.50	....	2.78	3.34
	3.82	....	....	3.44
	3.59	....	3.76	3.94
April	3.15	4.00	3.34	....
	4.10	3.71	....	3.62
	3.55	3.65	4.01	....
	4.46	3.76	....	....

These figures are taken from the reports of sales and prices on the New York auction market, in the New York *Daily Fruit Reporter.*

on equivalent dates of grade A apples from the different producing sections for the seasons 1925-26, 1926-27 and 1927-28.

The effect of grade and condition on prices is apparent in the fluctuations from day to day. Samples of different lots of fruit to be sold at auction are displayed before the selling begins, and sales by this method are therefore more likely to represent the comparative values of the different lots than are private sales. This explains individual prices which seem to be out of line with the general trend. For example, on the second reported day in December, 1926-27, New England McIntosh sold at an average price 21 per cent above the average for Montana on that day. This was a lot of generally desired sizes and doubtless of excellent quality, which brought the highest price of the season to date. Likewise the second March price (1926-27) shown for Montana apples was for a lot of combined "fancy" and "extra fancy" which ranged in price from $3.60 to $4.25 a box, bringing an average price of $3.88, according to the reports of the auction market, as published in the New York *Fruit and Produce Review.*

The McIntosh from the different producing sections sold through the New York auction market have been classified on the basis of percentages from each section at various prices during the seasons 1924-25 to 1927-28 (Table 3.)

It will be seen that during the three seasons when New England McIntosh have been sold at auction in New York, the majority of apples have been sold between $2.50 and $3.50 a box. During the season 1927-28, no New England McIntosh were sold below $2.75 a box, and 20 per cent were sold over $4.00. Only one per cent of those from the Northwestern States and 3.5 per cent of those from British Columbia brought prices equivalent to these during this season. More than one-fourth of all the McIntosh sold at auction during the season of 1927-28 sold for less than the lowest price received for any New England McIntosh.

In the season of 1926-27, the largest sales of Northwestern McIntosh (40 per cent) were at prices ranging between $2.00 and $2.25, and 70 per cent were sold at prices between $2.00 and $2.50. The greatest proportion of British Columbia McIntosh were sold between $2.50 and $2.75 a box, but the sales were much more evenly distributed than were the sales of the Northwestern apples. Nearly one-fourth of the McIntosh from New York State, sold at auction in 1926-27 brought from $2.75 to $3.00 a box, and 25.8 per cent brought more than $3.00 a box. Ten per cent of the New York apples sold between $1.50 and $1.75. Nearly half of the New England McIntosh sold at auction in 1926-27 brought an average price for the lot between $2.50 and $3.00; 8 per cent sold for less than $2.00 a bushel and 13 per cent for more than $3.00, the highest actual price recorded being $3.75. The highest price received for McIntosh from any section, $4.25 a box, was paid for some boxes in one lot of Montana apples. The average price, $3.63, for this lot was, however, not so high as some others.

Tracing a Carlot in New York.

The orchardists of New England have been much concerned as to the future of the McIntosh apple, since plantings of this variety have in recent years been large, particularly in Massachusetts and New Hampshire. There has been considerable fear that plantings have been too large, and that the market may soon be over-supplied with McIntosh.

Interest centers particularly about the market of New York City, which consumes more of all food products than any other market in the country.

Table 3.—Percentage of Volume of McIntosh from Various Producing Areas Sold at Auction in New York at Different Prices.

Seasons 1924-25 to 1927-28

	$1.50 or less	$1.51-1.75	$1.76-2.00	$2.01-2.25	$2.26-2.50	$2.51-2.75	$2.76-3.00	$3.01-3.25	$3.26-3.50	$3.51-3.75	$3.76-4.00	$4.01 and up
						NORTHWEST						
1924-25	....	2.9	....	2.9	5.7	12.8	39.9	19.4	4.5	2.1	9.8	....
1925-26	.6	....	13.9	6.1	12.1	51.5	6.1	3.0	6.4	....	....	....
1926-27	.4	....	5.9	39.7	29.8	10.7	8.6	1.9	1.2	1.4	.4	....
1927-28	....	....	2.1	2.3	9.1	22.4	27.8	19.2	11.7	3.5	.9	1.0
						BRITISH COLUMBIA						
1924-25	....	....	....	1.3	10.4	20.5	25.2	21.5	3.9	7.5	1.3	7.6
1925-26	....	....	....	....	3.9	4.8	4.3	35.2	19.5	....	8.6	23.6
1926-27	5.3	2.6	3.5	7.8	12.8	15.5	9.9	12.8	14.3	10.4	5.1	....
1927-28	....	....	....	....	4.1	5.5	17.9	24.6	26.7	12.7	5.5	3.5
						NEW YORK AND OTHER						
1924-25	....	....	6.8	....	4.4	9.8	....	....	34.7	9.7	8.8	25.8
1925-26	.6	1.7	3.0	2.5	19.1	42.0	24.5	5.3	.5	....	....	....
1926-27	....	9.9	13.6	8.1	....	18.4	24.2	18.4	7.4	....	....	....
1927-28	1.7	3.2	2.6	11.5	20.0	30.0	9.3	....	4.0	8.0	9.4	....
						NEW ENGLAND						
1924-25	....	....	....	....	....	....	....	....	....	....	....	....
1925-26	6.8	....	4.6	4.5	7.5	25.1	23.0	13.5	11.7	3.0	....	....
1926-27	....	4.7	3.4	17.2	13.9	25.8	22.4	9.2	....	3.4	....	....
1927-28	....	....	....	....	....	....	30.0	14.5	20.8	14.1	....	20.5

As it is situated in such close proximity to New England, it is of especial importance to New England producers.

In addition to the general information already obtained about the McIntosh in the New York market, it was decided to trace a carlot of New England McIntosh from the grower to the New York consumer, in the hope of learning specifically what happened to one shipment, how it was handled, how widely the apples were distributed, how many jobbers and retailers were concerned with the distribution, and the type of consumers to whom they were finally sold.

It was thought best to trace a carlot which had been stored in New England, and arrangements were made for securing information as to date of shipment of a car of apples packed by the Nashoba Apple Packing Association. Prices in the New York market were not high enough to attract shipments from Boston and it was not until late in March that the carlot traced was shipped to New York.

During the last week of March, 1928, a carlot of McIntosh apples, Docaway brand, packed by the Nashoba Apple Packing Association, was traced through the New York market. Consigned from cold storage in Boston to the firm of E. W. J. Hearty, Inc., the apples were sold at auction on Erie Pier No. 20 to eight jobbers and one chain of fruit stores, in lots ranging from 20 to 148 boxes. The variety being popular, the sales were very quickly made, and the prices were above expectations.

One hundred and sixty boxes of apples were distributed to The Bronx. Of these, 140 were bought by a chain of fruit stores; half of them were sold at the five stores in The Bronx, and the other half sent to the stores of the chain elsewhere—one near the Harlem Market, one in White Plains, one in Mamaroneck, one in New Rochelle, New York, and one in Stamford, Connecticut. Another lot containing 20 boxes was bought by a jobber in The Bronx who had not sold any at the end of the week devoted to the investigation. Manhattan received 150 boxes bought by three jobbers. Brooklyn received 280 boxes bought at auction by four jobbers, one of whom sold immediately to three other jobbers.

The jobbers sold these McIntosh in lots varying from one box to 20 boxes, the most common sale amounting to 5 to 10 boxes. The prices being higher than at any other time during the season, some of the apples did not move as rapidly as the jobbers seemed to expect.

The apples were traced to 47 retail stores, of which 10 belonged to a chain and 37 were individual stores. Thirty-one were fruit stores or stores that handle fruit and vegetables only. Thirteen were ranked as good stores, 9 as poor and 25 as medium. Retail sales were mostly by the pound, 28 of the retailers reporting selling by that method. Eleven sold by the apple and eight sold in both ways. The fruit stores sold by the apple, as is generally true of fruit stores. Sales by the pound were mostly reported by the Brooklyn dealers, while sales in Manhattan and The Bronx were chiefly by the apple.

Until this lot of apples was sold, the high price of McIntosh for the season had been about $3.75. The average price of these was $4.19, a considerable increase over the preceding high price. The apples were of three sizes: 125's, 138's and 150's. The 125's brought $4.15 a box; the 138's, $4.20; and the 150's, $4.30.[1]

Of the 47 retail stores handling these apples, 30 have a patronage chiefly, if not wholly, Jewish. Several of the retailers reported all their customers to be Jews. Some said that while their patronage is mixed as to nationality, the McIntosh apples which they handle are bought mostly by their Jewish customers. This bears out the statement often heard that McIntosh are bought in New York almost wholly by Jewish people. It is apparent that there is some ground for its nickname, "the Jew apple."

The popularity of this variety is further attested by the statements of the 47 retailers as to the ratio of McIntosh to the total volume handled yearly. Of the 46 who give details, five state that McIntosh comprise not more than one-fourth of their total volume of apples; 17 report between 25 and 40 per cent; 10 believe that between 40 and 50 per cent of their total sales of apples are McIntosh; five that from 55 to 75 per cent are of this variety; while nine say McIntosh comprise more than 75 per cent of the apples they sell. Two of this number say they handle no other variety.

Since these figures were estimates, it is possible that they are somewhat high, although there is no other reason for discounting them, as most of the dealers expressed great enthusiasm for the variety. It is undoubtedly safe to say that of 48,000 bushels of apples handled yearly by the 46 dealers reporting, 35 to 40 per cent are McIntosh.

The comments and suggestions of those handling these apples are of interest. Thirty-one prefer the McIntosh shipped in the fall to those that have been kept in storage till February. Some say the apples are not of as good flavor after they are held in storage, but the complaint is general that those shipped from storage in February do not keep as well. One dealer says he prefers those received late in the season, as he can make a better profit on them. Six report that they see no difference between McIntosh received in the fall and those received in February or March. It was a rather general complaint that this lot had been priced too high and therefore did not sell as rapidly as McIntosh usually do.

Some of the dealers expressed no preference as to the container, and opinions differed widely among those who had preferences. Some prefer boxes; some prefer barrels; one prefers cartons such as are used by some of the growers in the Hudson Valley area.[2] Some of the dealers who themselves prefer boxes said that their customers believe the best apples are packed in barrels, so apples bought in boxes are sometimes repacked in barrels so that the customers will think they are barreled apples. This practice was, however, virtuously condemned as "dishonest".

Some prefer boxes because apples "keep better" than if packed in barrels, while others believe just the opposite. One says his customers think apples

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[1] The Nashoba Apple Packing Association packed apples in the Western box for the first time in 1927-28. This accounts for the fact that the count is used in this portion of the study, whereas the prices in the discussion of size and premiums are for sizes. For convenience, there is given below a table of comparative sizes and counts:

Count	Size (inches)	Count	Size (inches)	Count	Size (inches)
263		150		80	
234	2 to 2¼	138		72	
216		125	2½ to 2¾	64	3¼ to 3¾
		113		56	
				48	
200		112			
188	2¼ to 2½	104	2⅞ to 3⅛		
175		96			
163		88			

[2] These cartons held fewer apples than a box, but contain fillers similar to those used in egg crates.

taste better if packed in barrels. Another suggests that all McIntosh be wrapped, as they arrive in better condition and keep better than those not wrapped. Some consumers think the wrappers "take the taste out."

Margins and Prices.

Two Brooklyn dealers carry McIntosh only because of the demand for them, as the retailer's margins on this variety are not high enough in that market. One said that he can not make more than 10 per cent profit on them.

The margins of the jobbers who handled these apples were low, but of course their costs were comparatively small and the turnover in most cases was rapid. One jobber sold his lot in a few hours for 31 cents a box above the purchase price and the charges. He paid $4.15 a box; 14 cents for cartage, etc., brought his costs to $4.29; and he sold for $4.60. One jobber who bought from one of the original purchasers asked $4.85 a box.

Prices at retail stores also varied. The chain of fruit stores made an average of $1.82 a box above charges and purchase price, selling mostly by the apple, although part were sold by the pound. The price per apple was five cents, and the price per pound 15 cents. This chain could sell many more McIntosh, "twice as many", if they were to be had. Indeed, other purchasers of these apples complained that they had to pay too high a price for them because the buyer for this chain was so anxious to get them that he paid more at the auction than the apples were worth to most dealers.

The reports of individual retailers indicate that their average gross margin was higher than that of the chain fruit stores. It is probably true, however, that their net returns are lower. The average gain on boxes sold by these individual stores was $2.197. These dealers sold also by the apple, but most of their sales were by the pound. The prices per apple were five cents, or six for 25 cents. There was a feeling among some who were asking five cents that they might have to reduce the price to four cents in order to get rid of them. It was apparently well recognized that these apples must be sold as rapidly as possible to prevent spoilage.

Sales by the pound ranged from 10 cents to 18 cents. Over half of those selling by the pound were asking 15 cents, although an occasional dealer asked 15 cents for one pound but would sell two pounds for 25 cents. One-third of those reporting sales by the pound were selling more or less at that rate. One dealer was asking 18 cents a pound, and one who was selling at 10 cents a pound was also asking 10 cents an apple.

Individually the gross returns ranged from $1.32 for one box of 150's sold at two pounds for 25 cents, to one box sold at a profit of $3.80. This does not include 10 boxes which the dealer said were being sold at 10 cents a pound or 10 cents an apple. If even four boxes of the lot were sold by the apple at this price, the returns would far exceed any other lot. It is doubtful, however, if many would be sold at that price when at the same store 10 cents would buy a pound.

The Nashoba apples are well and favorably known to "the trade" in New York. One or two of the retailers had not handled them before, but most of those who bought from this car knew them. There were several complaints of the condition of this lot, although some who complained said the brand was usually good.

Conclusions.

Two things seem evident from this investigation of the New York market:

1. The demand for McIntosh in New York has never been supplied, and the testimony of dealers indicates that the market will absorb many times what it now receives.

2. The New England McIntosh are in general equal to any that are received in New York, as indicated by the prices received.

6m-6-'28. No. 2618.

MASSACHUSETTS
AGRICULTURAL EXPERIMENTAL STATION

Bulletin No. 244 June, 1928

Type-of-Farming Areas in Massachusetts

By Ronald L. Mighell and Marian Brown

An adequate picture of Massachusetts agriculture is antecedent to a clear understanding of the farm problems of the State. This study supplies a part of that picture in brief graphical and descriptive form.

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AGRICULTURAL EXPERIMENT STATION

AMHERST, MASS.

Summary.

A knowledge of existing farming conditions and how they have developed is essential to wise farm planning and administration.

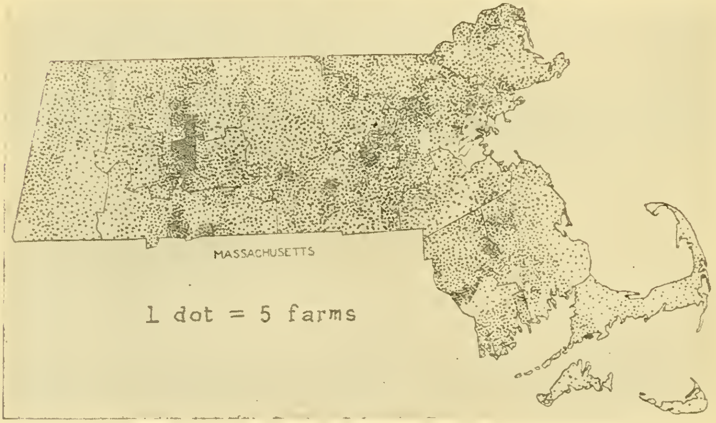
Topography, soils, and other natural factors have been and will continue to be important determinants in the decision as to the most profitable kinds of farming in Massachusetts.

The presence of a large industrial population, competition from other regions, and other economic factors have also been significant in determining the character of present-day agriculture.

This study distinguishes thirteen type-of-farming areas in Massachusetts. The boundaries of these areas are necessarily only approximate because of gradual transitions from one type to another.

The study shows the distribution by towns of the principal crop and livestock enterprises in Massachusetts according to the United States Census of Agriculture of 1925.

Figure 1. Distribution of Farms in Massachusetts, January 1, 1925.



TYPE-OF-FARMING AREAS IN MASSACHUSETTS

By Ronald L. Mighell, Assistant Professor, and Marian Brown, Laboratory Assistant, Department of Farm Management

Introduction.

The purpose of a type-of-farming study such as this is to provide a cross-section picture of the agriculture in a state or region at a particular time; to indicate the extent and limits of the chief areas where farm products and practices are similar; to show some of the physical and economic factors lying back of the differences, and thus to provide a more complete basis for recommendations and plans for future farming.

The term "type-of-farming" is usually associated with the idea of regional specialization. For example, there is a corn belt type of farming in the Middle West, a cotton type of farming in the South, and a dairy type of farming in New England. Type-of-farming has been defined as a form of organization and a method of operation, representative of a group of farms, in which there is a high degree of uniformity in such essential factors as selection of farm enterprises, farm practice, and method of disposal of products. In Massachusetts we have several distinct types of farming.

Figure 1 shows the location of Massachusetts farms on January 1, 1925. These farms differed from one another in size, topography, soil, crops, livestock, methods of operation, and in many other ways. The reasons for some of these differences are considered in the following discussion.

How Types of Farming Develop.

Why are some farmers dairymen, while others are poultrymen, or market gardeners? How does it happen that tobacco and onions are grown in the Connecticut Valley? What causes a concentration of apple production in the Nashoba district? All of these things arise as a result of the acts of individual farmers trying to make the most of the resources at their command. Their resources and the best use to make of them are determined by natural and economic conditions. The natural conditions of soil, topography, and climate are relatively permanent, while the economic forces are changing more or less continuously. Among the economic forces are such things as location of markets, transportation facilities, available capital, and state or city policies. For example, the increase in population in eastern Massachusetts has brought a milk supply from farther north and west. Rigid dairy inspection sometimes makes it difficult for milk to be shipped into a given locality and thus creates a market which would not otherwise exist for nearby dairymen. The organization of a cooperative packing association may make it possible to secure higher prices for apples through grading.

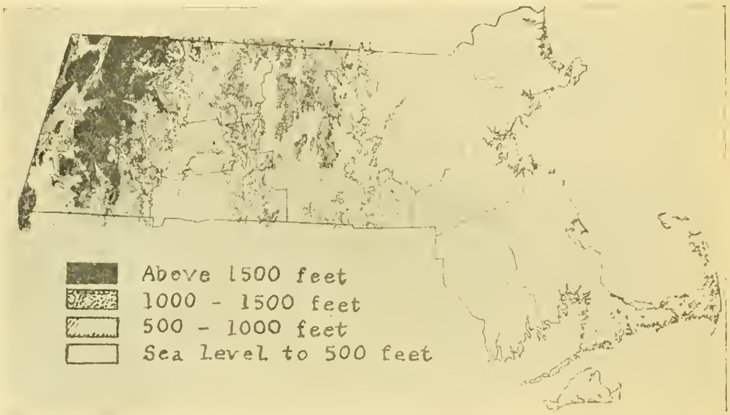
This study points out the chief physical and economic factors underlying types of farming in Massachusetts. It also shows the distribution of the principal crops and livestock according to the farm census of 1925, and marks out certain type-of-farming areas.

Physical and Economic Background of Massachusetts Agriculture.

The keynote of all future agriculture in Massachusetts was struck by that aboriginal inhabitant who christened the region "Massa-chusetts" or "great mountainplace," for if not all that the name implies, the surface of the state is certainly greatly diversified, being in the eastern and southeastern parts undulating to level; in the central section, hilly and broken; and in the western, rugged and mountainous. Consequently, as one man has written, "the state presents about every variety of soil, from the lightest and least productive to the strongest" and most productive.

The reason for the present surface of New England lies in the fact that the land has been longer above the surface of the sea than most other parts of the American continent. This has given more time for the action of successive glaciers and of wind and water. The upland tops of many of the present hills in central and eastern Massachusetts are all that remain of what was formerly a broad level plain. The less resistant portions of this plain have long since been carried away as the result of erosion. The accompanying diagram (Figure 2) gives an idea of the greatly dissected land relief which remains to us today. In general the land rises and becomes rougher as one goes toward the west, except in the level valleys of the Connecticut and Housatonic Rivers.

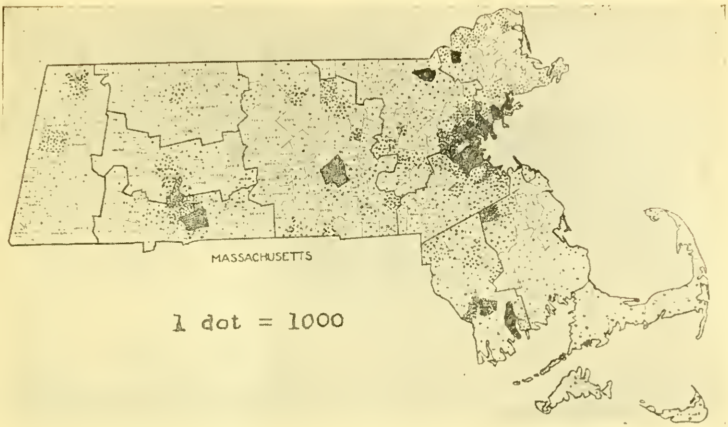
Figure 2. Land Elevation in Massachusetts.



Markets.

Figure 3 points out one of the most significant economic factors in present-day Massachusetts agriculture, the concentration of human population in large cities. More than four million people live within the limits of the Commonwealth. The location of much of this population on the eastern seaboard causes some differences in the agriculture of the eastern and western parts of the state, but an excellent system of hard-surfaced roads makes it possible for vegetable growers in the Connecticut Valley a hundred miles away, for instance, to place fresh produce on the Boston market daily. Massachusetts-grown products of high quality secure excellent prices. Espe-

Figure 3. Distribution of Human Population, January 1, 1925.



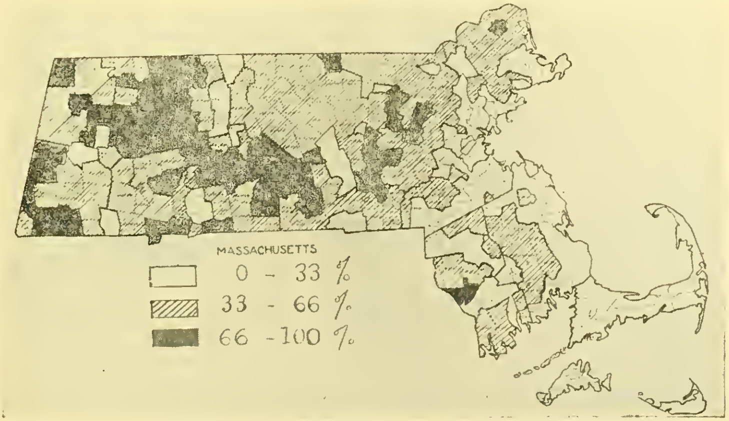
cially is this true of perishable or semi-perishable products such as vegetables, fruits, eggs, and so forth. Modern refrigeration has not yet sufficed to make every product from a distant land quite as fresh as that which is grown nearby.

The Character of Massachusetts Agriculture.

Massachusetts is not a large state. The midwestern state of Kansas, for example, is ten times the size and has approximately twenty times as much farmland. However, the greater unit value of Massachusetts products and the more intensive types of agriculture tend to make the state a far more important source of food supply than the extent of the land area would indicate.

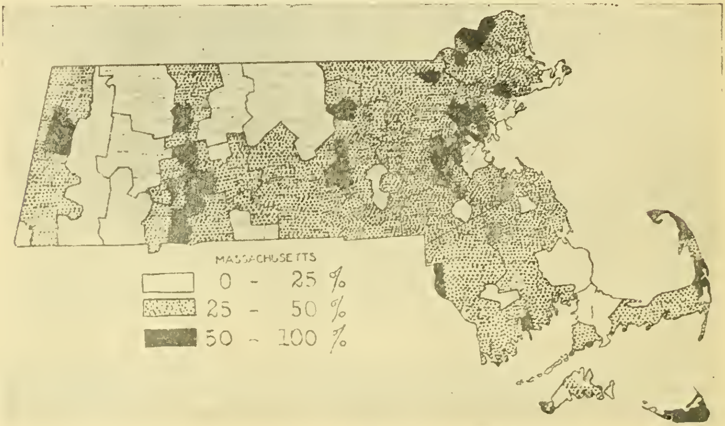
Figure 4 shows the proportion of land in farms in the different parts of the state. More than two-thirds of the land near the great cities, on Cape

Figure 4. Percentage of All Land in Farms.



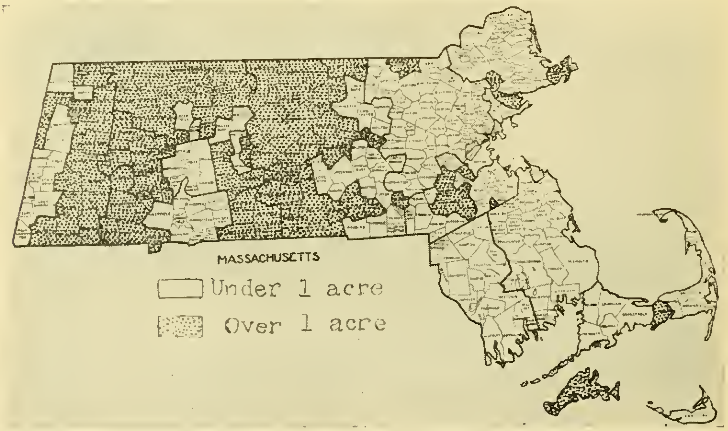
Cod, and in some of the hill towns is not in farms. Public parks, forest reservations, municipal water reservoirs, and other public lands cover a considerable area in addition to that which is merely waste.

Figure 5. Percentage of Farm Land Plowable.



The character of the land in farms is indicated in Figure 5, which shows the percentage of plowable[1] land. The lowest percentage is found in the Berkshire Hills and in the rough land of northern Worcester County. The Connecticut Valley as compared with other areas having a high proportion of land in farms has more plowable land than any other part of the state.

Figure 6. Farm Land in Pasture per Acre of Plowable Land.



The areas which have a low percentage of plowable land have the highest percentage of pasture. (See Figure 6.) This is not always an indication of plentiful pasturage, because many of the hill pastures are relatively unproductive. In general, however, there actually is more available pasture in these rough sections. Land too rough to till frequently grows a fair crop of grass. Available pasture is a factor which is significant in determining the most profitable types of farm organization. For example, it may be worth while to grow young stock with plentiful pasture when otherwise it would be very unprofitable.

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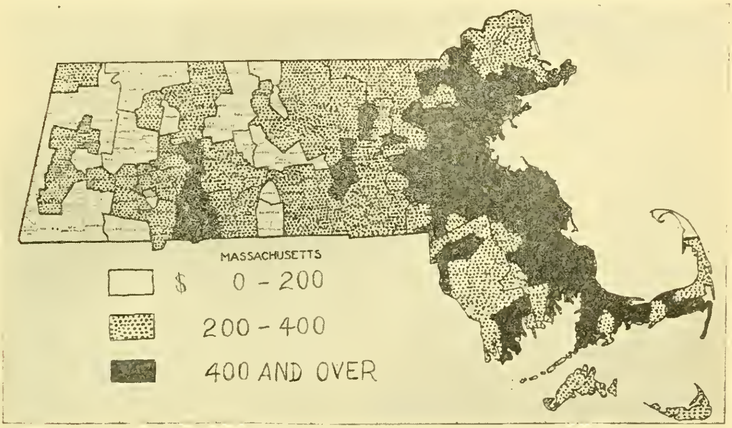
[1] Plowable land is crop land plus plowable pasture. Plowable pasture, as the term is used in the 1925 Census, comprises "land used only for pasture in 1924 which could be plowed and used for crops without clearing, draining or irrigating."

Farm land values in an industrial state are affected by many factors. The accompanying map (Figure 7) shows a much higher valuation in the eastern part of the state. Values in western Massachusetts with the exception of the Connecticut Valley are lower, due to greater distance from the cities as well as to differences in natural productive capacity of the land. Land near cities is often valued for urban use as well as for farming.

Figure 7. Value of Land and Buildings per Acre of Plowable Land.



Type-of-Farming Areas.

A single enterprise, such as dairying, might be used as a basis for dividing the state into areas marking different kinds of farming. Farmers, however, generally carry on several lines of production at the same time and so a single enterprise map is usually not sufficient for such a division. In this study the relative proportions between the several principal crop and livestock enterprises in the towns of the state have been used as the basis for division, due consideration being given to the underlying natural and economic factors.

The method used was to express census figures for individual crops and livestock on the basis of so many acres or so many head of stock per farm and per 100 acres of plowable land. These were calculated for each town.[2] Similar towns were then grouped on the basis of acreage or numbers of the more important crops or livestock. In this fashion the areas shown in Figure 8 were finally determined.

It must be made clear at the outset that the boundary lines are only approximate, for in many cases a change in type of farming comes as a gradual

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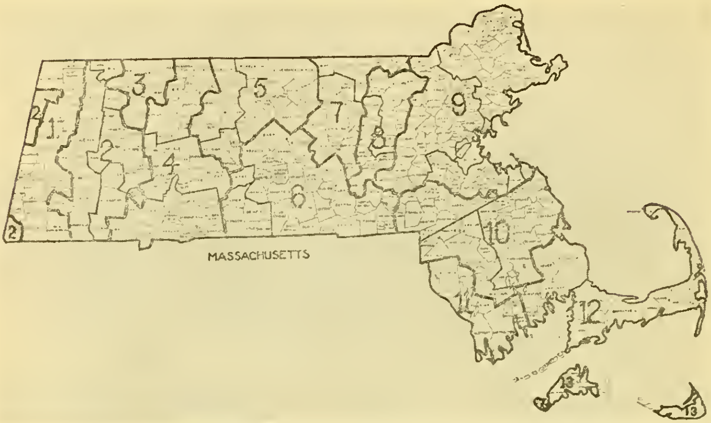
[2] "Town" in this sense in New England has the same meaning as "Township" in other parts of the United States.

Figure 8. Type-of-Farming Areas in Massachusetts.



1. Housatonic Valley
2. Berkshire Hills
3. West Franklin
4. Connecticut Valley
5. North-Central Upland
6. South Worcester
7. Northeast Worcester
8. Nashoba
9. North of Boston
10. South of Boston
11. South Bristol
12. The Cape
13. The Islands

transition from one area to another. There are also many local variations within the areas because of the natural and economic differences. However, each of these areas has certain characteristics which set it apart from the others. Town lines were adhered to in drawing in the boundaries, because the town is the smallest unit for which census figures are available. Very often, of course, it would be more nearly correct to draw a line through the center of a town rather than around it.

The tables in the appendix present the statistical data showing the differences between areas, and the following brief discussion and the maps of the various crops and livestock show the principal characteristics of the areas outlined above. It will be noticed that the western areas correspond very closely with the natural land surface. Area 7 in northeast Worcester is transitional in type of farming between the Nashoba apple district and the upland to the west. The outlines of the North of Boston and South of Boston areas are less sharply marked than are those of the western areas and more kinds of farming are included.

Housatonic Valley.

The narrow valley of the Housatonic is bounded by the Taconic Range on the west and by the Berkshires on the east. This is the one section of the state with natural limestone deposits. Dairying is the principal farming enterprise. It is frequently combined with the raising of young stock. Poultry and egg production are of little importance except in a few towns. There are few commercial orchards. The Valley has a number of fine estates and summer houses of city people. The southern part, in the region about Sheffield and Great Barrington, has a higher percentage of plowable land than the northern end of the Valley, which is much more hilly.

Berkshire Hills.

This area includes the border towns of the Taconic Range as well as the region of the Berkshire Hills. As a whole it is rough and the percentage of plowable land in farms is the lowest in the state. There are many small forest reserves scattered through the area, the town of Washington being almost all in reservation. The percentage of farm woodland is also high. Dairying is the chief farming enterprise. Income from this source is supplemented in different sections by wood products, maple sugar, apples, miscellaneous cash crops, and outside employment. Formerly sheep-raising was important.

West Franklin.

West Franklin contains most of the commercial orchards of the western part of Massachusetts. Dairying is even more important than the production of fruit. There are more dairy cows and more apple trees per hundred acres of plowable land than in any area west of the Nashoba fruit belt. The land surface rises abruptly from the valley of the Deerfield River and is very rough.

Connecticut Valley.

The Valley is an area with many types of farming. It is a narrow strip of extremely fertile land extending a few miles on either side of the river and then gradually rising to the Berkshires on the west and the low hills of Worcester on the east. Tobacco, onions, and market garden crops are grown. Dairying is the chief enterprise on general farms and in four or five towns fruit growing and poultry production are significant.

North-Central Upland.

The North-Central Upland area takes in a large amount of very rough, unproductive land. This is especially true of the southwestern part of this area. The new Boston Water Supply Reservoir will eventually cover most of the region about Enfield, Greenwich, and Prescott. The whole area has a high percentage of farm woodland and pasture. Dairying is the principal source of income. Hay is the chief roughage feed, because the short growing season reduces the yield of corn.

South Worcester.

South Worcester is a dairy section. There are a few commercial orchards, but dairying is the chief source of livelihood. Poultry is only a minor enterprise except in certain towns. There is an abundance of roughage, both hay and silage and fodder corn, as compared with the northern part of the county. The elevation is also less and the topography not as rough, although a land surface of low hills is the rule.

Northeast Worcester.

Dairying, apples, and poultry lead in this area. The section lies on the western edge of the Nashoba fruit area and the farming systems are intermediate between those of that area and of the hilly section to the west. Poultry and egg production has been increasing. Strawberries are grown in Lunenburg.

Nashoba.

The Nashoba belt is the intensive, commercial apple area of Massachusetts. It lies partly in Middlesex County and partly in Worcester. In addition to farms devoted to orchards exclusively, there are many farms which combine dairying with apple growing. Other enterprises are poultry and vegetable crops for the Boston market.

North of Boston.

The North of Boston area here outlined includes the areas lying about Boston and the cities on the Merrimac River and the intervening territory. Dairying and poultry raising are generally distributed over the whole area. Market gardening is centered in towns such as Concord and Danvers and near the cities. Apples also are grown in the towns near the Nashoba area and in some of Essex County.

South of Boston.

Poultry and egg production is followed to a greater extent South of Boston than to the north, particularly when compared with other farm enterprises. The area includes some diverse types of farming from dairy farms in the west to poultry and truck farms in the eastern part. The elevation over the whole area rarely exceeds 200 feet except in Norfolk County.

South Bristol.

Fall River and New Bedford lie in South Bristol, and Providence is just over the state line. This makes a system of excellent markets for the products of the section. The upper part of the area is an intensive market garden district. There are more dairy cows per hundred acres of plowable land in this area than in any other in Massachusetts. It is one of the few areas in Massachusetts in which the number of cows has been increasing. The number of poultry on farms is also very high.

The Cape.

Only a small percentage of the land on the Cape is in farms. The cranberry crop is the source of most income. Poultry and dairying are important with some individuals. Falmouth is famous for strawberries. Many of the people have outside sources of income in addition to the receipts from the farm.

The Islands.

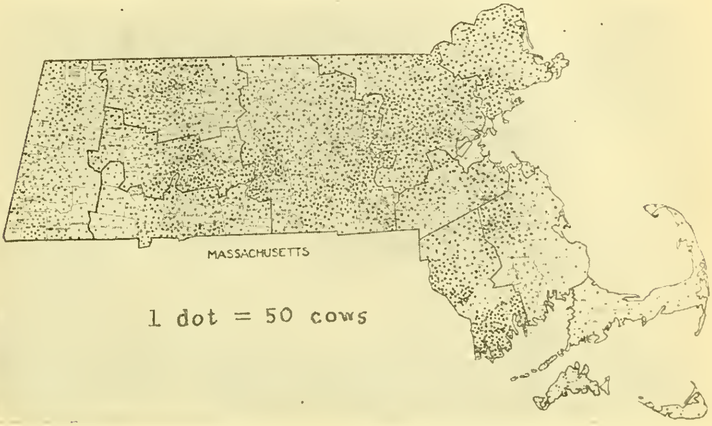
The Islands include two counties, Dukes and Nantucket. Marthas Vineyard and the Elizabeth Islands make up Dukes County; and the island of Nantucket, the County of Nantucket.

There are 117 farms in Dukes County and 25 farms in Nantucket. This is a smaller number of farms in relation to plowable land than on the mainland. The average temperature is from 10 to 20 degrees warmer than in central Massachusetts in winter. Dairying is the principal enterprise.

Distribution of Individual Crops and Livestock.

A study of the distribution of each of the principal crops and livestock gives a clearer picture of the agriculture of the state and of the different areas than does the preceding discussion taken by itself. A careful consideration of the maps on the following pages shows the degree to which the various enterprises are correlated with one another and with the natural and economic factors affecting their distribution.

Figure 9. Dairy Cows on Farms, January 1, 1925.



Dairying.

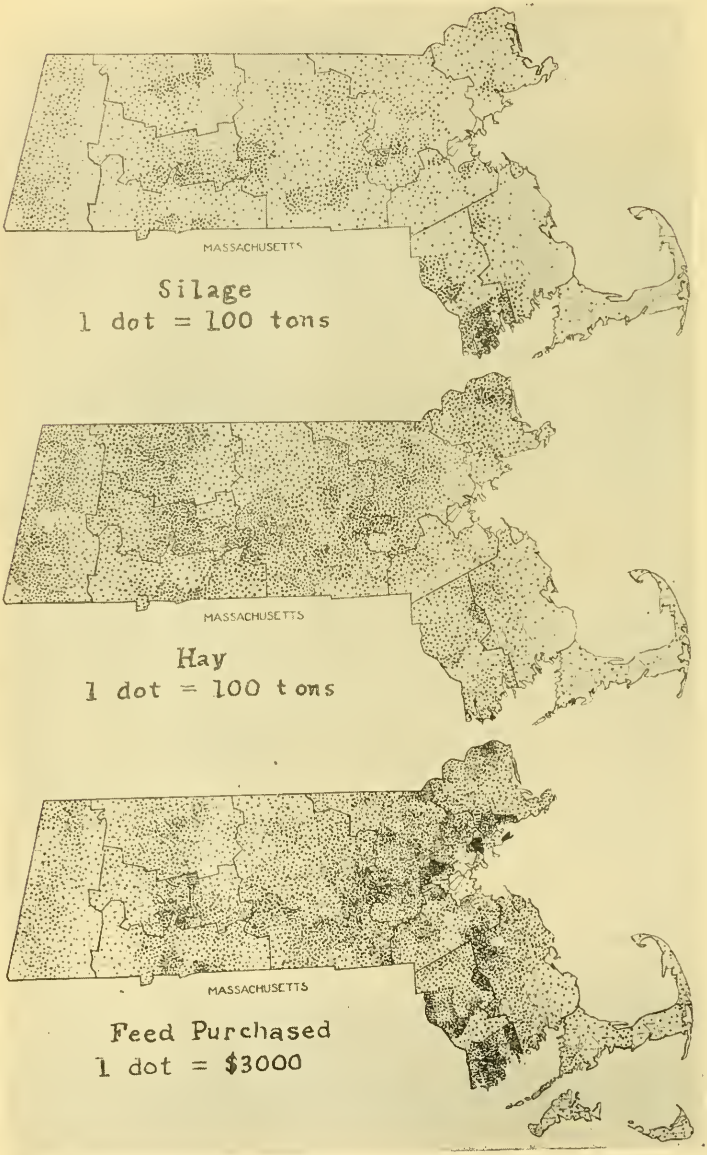
Dairying is the most important single source of farm income in Massachusetts. Figure 9 indicates the wide distribution of dairy cows. Comparison with the topographic map shows that the areas more sparsely populated with cows correspond with the rough land in the Berkshires and in the North Central Upland. The Cape region likewise has a small number of cows. Many factors have combined to bring about this wide distribution of dairy cows as well as their lack of concentration in certain areas. The primary ones are probably physical or natural, although economic factors such as proximity to markets are also very significant.

The distribution of the chief feed crops and of feed purchased is shown in Figure 10. Most dairymen, except in some places in the eastern end of the state, grow enough roughage to supply their cows, and so the distribution of hay and corn closely follows that of dairy cows. In the case of corn, production falls off rather more sharply in sections at higher elevation than does hay production, as might be expected. Considerably more feed is purchased in the eastern part of the state than in the western. This is partly because cows are fed more heavily of concentrates in that part of the state, and partly because purchased feed also includes poultry feed, of which there is a greater quantity purchased in eastern Massachusetts.

Poultry.

Poultry and egg production have been increasingly important in recent years. Figure 11 shows the distribution of poultry on farms on January 1, 1925. There is more poultry in the eastern areas of the state, although some western towns also have a large number. Poultry production is carried on both as a specialized, single-enterprise business and as a supplementary part of a general farming system.

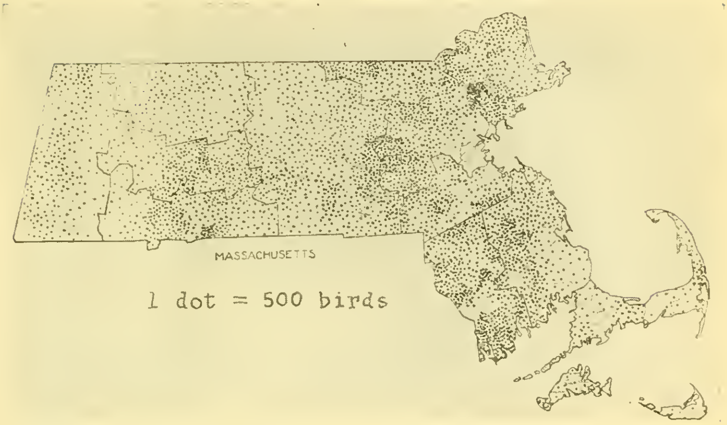
Figure 10. Distribution of Silage Corn, Hay, and Feed Purchased in Massachusetts, 1924.


MASSACHUSETTS
Silage
1 dot = 100 tons
MASSACHUSETTS
Hay
1 dot = 100 tons
MASSACHUSETTS
Feed Purchased
1 dot = $3000

Apples.

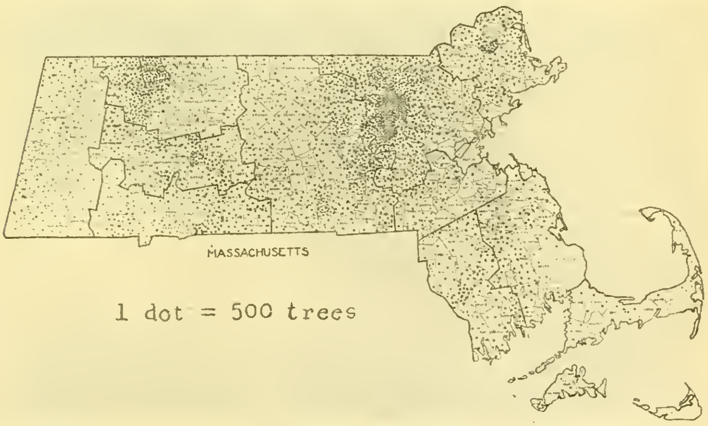
Commercial apple production is carried on in the Nashoba belt, in Franklin County, and in scattered towns in other parts of the state. (See Figure 12.) The apple industry of New England has recently been the subject of a special study in each of the New England states and the published results of these studies have been available for some time.

Figure 11. Poultry on Farms, January 1, 1925.



In Massachusetts, orchards are frequently a sole source of income, but very often fruit growing is combined with some supplementary enterprise or enterprises. Dairying is perhaps most often combined with orcharding to complete the farming system. Poultry, vegetables, and various minor crops are also often included in the combination.

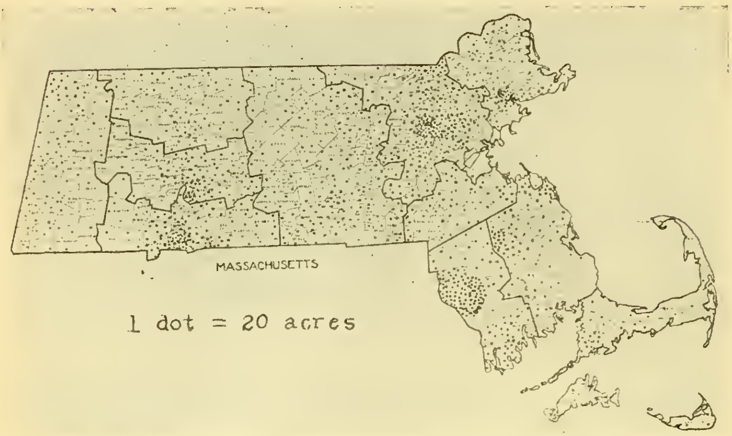
Figure 12. Bearing Apple Trees, January 1, 1925.



Market Gardening.

There are several market garden sections in Massachusetts, and a number of minor centers where a specialty is made of one or more crops. The three chief areas are the Boston area, centered about Concord and Danvers; the Providence area, including the Massachusetts towns near Providence, Rhode Island; and in the Connecticut Valley. (See Figure 13.) Of these, the first named is by far the most important. Greenhouse vegetables are extensively grown there, as well as the out-of-door vegetables. Minor areas are found

Figure 13. Distribution of Out-of-Door Vegetables.



near Worcester, Fitchburg, and Bridgewater. The scattered dots in Figure 13 chiefly represent potatoes and miscellaneous vegetables grown on general farms as cash crops.

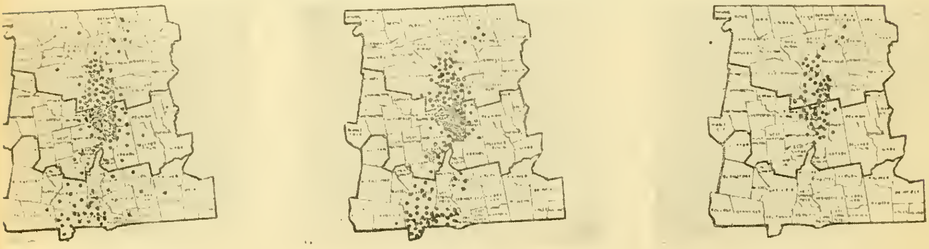
Tobacco and Onions.

Tobacco and onions are specialized intensive crops rather closely confined to a few towns of the Connecticut Valley. This is particularly true of onions. As seen in Figure 14, the onion and tobacco towns coincide in the north while the tobacco extends south and ultimately on into the larger tobacco area in the state of Connecticut.

Both crops are grown on small acreages, with large amounts of hand labor, and heavy applications of fertilizer. The fertilizer diagram gives an indication of the dependence of these two crops on commercial fertilizer.

Growers of these crops have recently been faced with lowered prices and a declining demand for the particular type of product which is grown in the Valley. These factors may eventually make changes in the present type of farming.

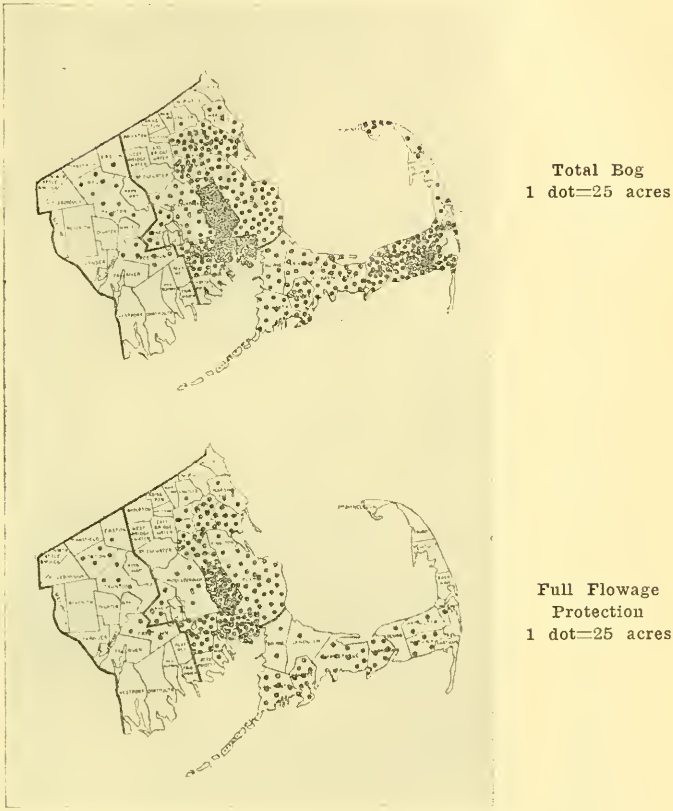
Figure 14. Distribution of Fertilizer, Tobacco and Onions in the Connecticut Valley, 1924.


Fertilizer
1 dot=$10,000

Tobacco
1 dot=50 acres

Onions
1 dot=50 acres

Figure 15. Massachusetts Cranberry Bogs.



Cranberries.[3]

Massachusetts produces about 60 per cent of the annual cranberry crop of the United States. Cranberries are grown on the bog or muck lands of Barnstable and Plymouth Counties. A few bogs are also to be found in Bristol, Dukes, Essex, Middlesex, Norfolk, and Nantucket. The accompanying chart (Figure 15) shows the distribution of cranberry bogs by towns. Carver and Wareham, Rochester and Plymouth have the most bogs per unit of land area. Cranberry bogs range in size from one acre to 258 acres. The average size is 6.5 acres and over 85 per cent of all holdings are less than 10 acres in size. However, out of 2149 holdings, 111 of 25 acres or more contain almost half of the total bog acreage.

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[3] Data on cranberries obtained from "Cranberry Acreage and Production in Massachusetts." New England Crop Reporting Service, Boston, Massachusetts; July, 1925.

Appendix

Number and Size of Farms, Acreage of Crops and Number of Livestock per Farm and per 100 Acres of Plowable * Land in the Thirteen Type-of-Farming Areas of Massachusetts—January 1, 1925.

Type-of-Farming Area	No. of Farms	Average Size of Farm *Acres*	*Farm Land Plowable Per Cent*	PER FARM								PER 100 ACRES PLOWABLE LAND							
				Pasture Acres	Woodland Acres	Dairy Cows No.	Poultry No.	Apples Trees	All Corn Acres	Hay Acres	Vegetables Acres	Pasture Acres	Woodland Acres	Dairy Cows No.	Poultry No.	Apples Trees	All Corn Acres	Hay Acres	Vegetables Acres
Housatonic Valley	2001	114.3	*38.5*	44.2	42.4	7	52	30	2.2	29.9	.7	100.5	96.5	15	118	68	5.0	68.0	1.5
Berkshire Hills	1763	164.2	*19.9*	72.6	98.0	4	33	33	.7	26.1	.6	222.8	300.8	13	100	100	2.0	80.1	1.7
West Franklin	841	129.7	*22.9*	79.9	57.6	6	39	149	1.4	22.7	.5	269.3	191.4	21	131	503	4.8	76.5	1.5
Connecticut Valley	5369	62.3	*38.1*	22.4	25.5	4	49	29	2.0	12.1	.9	94.6	107.5	16	205	122	8.5	50.8	3.6
North-Central Upland	2163	80.0	*22.1*	35.0	51.0	3	41	24	.5	13.8	.4	197.4	288.1	16	233	134	2.9	77.9	2.3
South Worcester	4103	82.1	*30.7*	37.6	44.9	5	51	34	1.2	18.2	.6	149.0	178.1	20	202	136	4.8	72.3	2.3
Northeast Worcester	1996	60.9	*35.0*	24.2	28.9	4	63	60	.8	14.2	.5	113.6	135.6	20	295	281	3.7	66.4	2.4
Nashoba	2203	58.3	*41.9*	18.2	19.6	4	73	328	.9	14.4	.6	74.4	80.3	18	298	544	3.5	59.0	2.6
North of Boston	5533	48.5	*40.6*	12.9	16.6	5	75	43	.8	11.1	1.4	65.3	84.3	24	379	220	8.1	56.4	6.9
South of Boston	3965	45.5	*35.4*	8.7	22.5	3	85	25	.6	8.0	.7	54.2	139.9	19	526	158	3.7	49.5	4.2
South Bristol	1805	48.8	*35.8*	13.8	19.9	6	87	22	2.1	8.0	1.5	79.2	114.0	33	496	128	13.9	45.8	8.6
The Cape	1481	51.2	*31.0*	7.5	24.4	2	58	10	.5	3.3	.5	47.4	153.4	13	365	65	3.2	20.5	2.9
The Islands:																			
Dukes County	117	177.6	*21.9*	54.9	89.1	5	60	11	.9	8.2	.6	141.1	229.1	13	154	29	2.4	21.0	1.4
Nantucket County	25	198.1	*59.4*	99.2	.6	12	82	. .	3.1	33.6	2.3	84.2	.5	10	69	. .	2.6	28.5	1.9

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* Plowable land is crop land plus plowable pasture. Plowable pasture comprises land used only for pasture in 1924 which could be plowed and used for crops without clearing, draining or irrigating.

3M—7-'28. No. 2855

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 245 June, 1928

Blight and Leaf-spot of Carrot in Massachusetts

By W. L. Doran and E. F. Guba

Blight and leaf-spot of carrot are foliage diseases which occur in Massachusetts with varying degrees of severity according to the character of the season. At the request of growers, the Experiment Station has made a study of the economic importance, causes and control of the two diseases. Results are reported in this bulletin.

Requests for bulletins should be addressed to the

AGRICULTURAL EXPERIMENT STATION

AMHERST, MASS.

BLIGHT AND LEAF-SPOT OF CARROT IN MASSACHUSETTS

By W. L. Doran, Research Professor of Botany and E. F. Guba, Assistant Research Professor of Botany*

Blight and leaf-spot of carrots are not new in Massachusetts. In the very rainy summer of 1920, these diseases were unusually conspicuous and consequently there was a suddenly increased interest in them on the part of some of the growers who wished to know whether or not it would be profitable to attempt to protect carrots against them, and how. As a result, investigations of their real economic importance, cause, and control were undertaken, and the results of these investigations are here presented.

Economic Importance

These diseases may cause loss by reducing the yield of carrots, or the presence of the fungi on the petioles of the leaves may so weaken them as to make the pulling of the roots more difficult, with consequently increased cost of harvesting. According to Clayton (1)[1], the roots are more susceptible to decay following an attack of carrot blight.

The first crop of carrots is planted in Massachusetts as early as the soil can be prepared, and is harvested when about half grown to be marketed in bunches. Neither of these diseases has caused any appreciable loss on early or bunch carrots in this state. However, according to Chupp (2), carrot blight in some sections of the country reduces the market value of carrots sold in bunches by making the leaves unsightly.

The main crop of carrots is planted later, that is, early in June, and is harvested about the last of October to be topped and stored for fall or winter marketing. Blight and leaf-spot are generally present on late carrots and it is usually on the late crop that they have caused loss here.

In Massachusetts, the economic importance of these diseases of carrots is not great in the average season. In the rainy summer of 1922 when the diseases were very conspicuous, the yield per acre at the Market Garden Field Station in Lexington was only 11 per cent below the average. The diseases are not important causes of lowered yields here except in summers of unusually heavy rainfall.

Symptoms

Leaf-spot and blight are often present together on the foliage, so that from the viewpoint of the market gardener they may constitute one disease.

The leaf-spot disease may occur at any point on the leaf although it is most common on the margin. The spots are circular except when their position on the margin of the leaves makes them semicircular. The spots have a diameter of 2 to 5 mm. (about $\frac{1}{16}$ to $\frac{3}{16}$ inches), and they often coalesce to form larger spots. The center of the spot is grayish brown and is usually surrounded by a narrow yellow or straw-colored zone. On the lower surface of the spots a grayish weft of the causal fungus is sometimes visible to the naked eye. Leaf-spots on the petioles are more elongated and are slightly darker in color than the spots on the blade of the leaf.

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* The investigation here reported was carried through the first season by W. S. Krout, formerly Assistant Research Professor of Botany.

[1] Numbers in parentheses refer to "Literature cited", p. 278.

The blight disease appears first as indefinite brown areas with pale yellow centers near the margins of the leaves. Individual teeth of the leaflet turn brown followed by the browning of the leaflet and entire leaf. Sometimes entire leaves turn yellow and then brown and black without the conspicuous presence of the scattered brown areas. Lesions of blight are not as nearly circular nor as sharply defined as are those of leaf-spot. The blight is the more severe of the two diseases and may cause the death of entire leaves. The mass symptoms of blight are more striking than are those of leaf-spot. The foliage of a carrot field in which blight is severe may appear as if burned by heat. Both diseases are much more common on the older leaves of the plants.

Of the two diseases on the main crop of carrots, leaf-spot appears earlier in the season and is generally found during the middle of the summer, and blight does not often appear until late summer. This is probably due principally to differences in susceptibility coincident with growth of the foliage, a point which is further discussed. Although either disease may be found in the absence of any appreciable amount of the other, it is more common for blight to be prevalent following the earlier appearance of leaf-spot in a field.

Causes of Leaf-spot and Blight

Leaf-spot of carrot is caused by the fungus *Cercospora apii carotae* Pass. (3). Blight of carrot is caused by the fungus *Macrosporium carotae* Ell. and Langlois (4).

These fungi have been found constantly associated with the respective diseases in Massachusetts and their pathogenicity here has been established.

Plants Attacked

There is no evidence that the fungi which cause blight and leaf-spot of carrot occur on any other cultivated plants.

Leaves of carrot, parsnip, parsley, and celery were inoculated with *Macrosporium carotae* isolated from carrot foliage, but of the plants inoculated only carrots became infected.

Klotz (5) has shown that *Cercospora apii,* from celery, is not transferable to carrot, and he did not secure infection on celery when he used as inoculum the Cercospora isolated from carrot.

The fungi which cause blight and leaf-spot occur on and have been isolated from both wild and cultivated carrot. Cultivated carrots have been inoculated and infected with these fungi isolated from wild carrots. The wild carrot is a common weed in Massachusetts, and if it grows near a field of cultivated carrots it may serve as a source of infection for the latter.

Relation of Temperature and Moisture to the Germination of Spores of the Fungi

Since the germination of fungous spores is prerequisite to infection, a brief consideration of some of the factors which affect the germination of the spores of these fungi is of interest.

The spores of the blight fungus, *Macrosporium carotae*, were found to germinate well at all temperatures between 61° and 82°F. They germinated best at temperatures between 72° and 75°F. The temperatures most favorable for the germination of the spores of the blight fungus are relatively high.

The spores of the leaf-spot fungus, *Cercospora apii carotae*, germinated best at a temperature of 75° to 78°F.

The spores of both fungi were found to germinate well through a relatively long range of temperature, and it is not likely that summer temperatures are often an important factor affecting infection by these fungi in Massachusetts. In the case of both diseases, there is more likelihood of the weather late in the summer being too cool than too warm for their development.

Water on the leaf is necessary for germination of the spores of the blight fungus, *Macrosporium carotae*. An average of only 6 per cent of these spores germinated in moisture-saturated air as compared with 100 per cent which germinated in water. The leaf must be wet, but these spores germinate quickly and two hours in water is long enough to permit germination.

The spores of the leaf-spot fungus, *Cercospora apii carotae*, germinated well in moist air, but only after they had been previously soaked in water for one or two hours.

These findings are in accord with the field observations to the effect that the severity of these diseases on carrot is usually proportional to the rainfall of the season.

Infection

The germ tubes which grow out of the spores during their germination penetrate the carrot leaves and infection results.

The average length of time between inoculation and the first appearance of the symptoms of disease on the leaves, or the period of incubation, was found to be eight or nine days in the case of the leaf-spot fungus, *Cercospora apii carotae*, and about fourteen days in the case of the blight fungus, *Macrosporium carotae*. The air temperatures during the period of incubation were between 67°F. (nights) and 86°F. (days).

As was anticipated from experiments on germination, it was found that the leaves must be wet and must remain wet for more than two hours for blight infection to occur. If, during the germination of the spores of the blight fungus, *Macrosporium carotae*, on a wet leaf, the leaf became dry and remained so, the germinating spore was killed. A short rain immediately followed by drying sun and wind may result in the death of these spores rather than in their germination. However, carrots are planted so thickly that any rain causes the foliage nearest to the soil to remain wet long enough to permit some infection.

There is an interesting and rather important relation between the age of carrot leaves and the degree of their susceptibility to blight. The oldest and the youngest leaves were removed from plants, placed in moist chambers and inoculated with the spores of the blight fungus, *Macrosporium carotae*. None of these leaves showed any evidence of natural infection, and uninoculated check leaves in moist chambers never became infected. The experiment was repeated five times and in each case three weeks after inoculation the number of blight spots on young and on old leaves was counted. There was an average of twenty-four points of infection on old leaves for each point of infection on young leaves. The leaves most susceptible to the blight fungus were those which had reached such an age as practically to cease growing.

Blight causes little loss on bunch carrots for they are harvested before the leaves have reached the most susceptible stage. Carrot leaves up to eight weeks of age are relatively resistant to the disease and after that susceptibility increases with age.

Young leaves of carrot are, however, not resistant to leaf-spot, and plants as young as sixteen days old may be infected. But leaf-spot alone is of less importance on the carrot here than is blight, and the symptoms of the former early in the season are rarely conspicuous.

Overwintering of the Fungi Which Cause Blight and Leaf-spot

The spores of the blight fungus, *Macrosporium carotae,* were found to live through the winter in the soil. Spores collected in the field during the winter and spring always germinated. Freezing the spores in ice did not kill them, but rather was followed by an increased percentage of germination.

The mycelium of this fungus was found to be living in carrot refuse in the field as far into the winter as January 15. But attempts to isolate the fungus the following April from mycelium in carrot refuse in the field were not successful.

The leaf-spot fungus, *Cercospora apii carotae,* was found to live through the winter in fragments of carrot leaves in the form of mycelium. Leaves with leaf-spot were buried in the soil in the field in October. The following April the fungus was isolated from the mycelium in these leaves.

The spores of the leaf-spot fungus obtained in the winter and spring from fragments of carrot leaves in the field did not germinate.

Since blight and leaf-spot sometimes occur on the inflorescence of the carrot, the possible relation of carrot seeds to overwintering of the fungi was considered. However, neither of the fungi was found in or on the seeds. Carrot seeds from diseased plants were plated on agar but neither of the fungi developed.

In this connection it may be noted that Klotz (5) did not find on the seeds of celery the closely related fungus, *Cercospora apii,* which causes early blight of this crop.

Since the fungi were not found on carrot seeds, there is probably no reason for market gardeners to disinfect the seeds of carrot for the prevention of blight and leaf-spot. In any case, it is unlikely that seed treatment would materially reduce infection in the field because both fungi are generally present and can winter-over in fragments of diseased carrot leaves in the soil.

Dissemination of the Blight Fungus

In the fall when carrots are harvested, crumbling fragments of decaying leaves which have been lying on the soil form part of the dust in the air. Great numbers of spores of the blight fungus, *Macrosporium carotae,* are present. Slides coated with adhesive were exposed 100 yards from carrots when they were being harvested, and many spores of this fungus were caught upon them. The fungus is doubtless disseminated in other ways, but the spores which are borne by the wind are probably an important means of disseminating the fungus to fields not previously used for carrots.

Laboratory Experiments with Fungicides

Toxicity tests were made by the method of Reddick and Wallace (6).

Bordeaux mixture, 2-2-50, was found to prevent all germination of the spores of the blight fungus, *Macrosporium carotae;* and Bordeaux mixture, 1-1-50, permitted slight germination, only 4 per cent as compared with 100 per cent in the check.

Micro-slides were lightly dusted with a copper dust containing 9.5 per cent monohydrated copper sulfate. These slides were then sprayed with water and dried for twenty-four hours, when drops of water containing the spores of this fungus were placed on them. There was no germination of the spores in the presence of the copper, and the germination of check spores was 100 per cent.

The spores of the leaf-spot fungus, *Cercospora apii carotae,* were found to be even more susceptible to the toxic action of a copper fungicide. Bordeaux mixture 1-1-50, tested by the method of Reddick and Wallace, prevented all germination of these spores.

A copper fungicide which controls blight may be expected to control leaf-spot of carrot.

The effect of sulfur on the germination of the spores of the blight fungus, *Macrosporium carotae,* was determined. Blighted leaves of carrot were dusted with sulfur and placed at controlled constant temperatures, as were also blighted leaves not sulfured. At hourly intervals spores were removed and placed under optimum conditions for germination. It was found that sulfur is not toxic to the spores of this fungus. Even after as much as twenty hours' exposure to sulfur at a temperature as high as 87°F., these spores germinated well, and as well as spores not sulfured. Previous wetting of the spores did not affect their great resistance to the toxicity of sulfur. It is evident from this that sulfur cannot be expected to protect carrot foliage against infection by blight.

In this connection it is of interest to note that the spores of the closely related fungus, *Alternaria solani,* which causes early blight of potato, were found by Doran (7) to be very resistant to the fungicidal action of sulfur.

Spraying and Dusting Experiments in the Field

Field experiments with copper fungicides for the control of blight and leaf-spot of carrot were conducted in five years. In two of them, 1921 and 1922, blight was more than usually severe. In three of them, 1923, 1925, and 1926, there was but little blight.

For lack of more suitable equipment at the time, the spraying was done by carrying a long hose through the carrots from a power sprayer at the end or side of the field. Aside from the inconvenience of this method, the carrots were well sprayed.

In 1921, carrots were sprayed with Bordeaux mixture 4-6-50 at intervals of about eleven days beginning August 22 and ending October 14. The yield per acre was 15 per cent greater on plots sprayed than on plots not sprayed.

In 1922, carrots were sprayed with Bordeaux mixture of the same formula at intervals of about ten days, beginning August 21 and ending October 15. In that year, the yield of carrots per acre was 22 per cent greater on sprayed plots than it was on plots not sprayed.

In 1923, 1925, and 1926, years of little blight, spraying carrots with Bordeaux mixture 4-4-50 or dusting with a standard copper-lime dust, by the schedule of applications used in the previous years, did not result in any increases in yield over the yield on plots not sprayed or dusted.

According to Chupp (2), some of the growers on Long Island have practiced spraying carrots with Bordeaux mixture for the control of blight, evidently with satisfactory results.

On the basis of the results of the experiments and observations of the writers, however, spraying carrots with Bordeaux mixture is not likely to be profitable in Massachusetts except in the very worst years of blight. Since they cannot be predicted, and since the loss caused by blight and leaf-spot in the average season is not sufficiently great here to warrant much extra expense for control measures, the writers do not recommend that carrots be sprayed every year.

In a rainy season when the indications are that blight and leaf-spot will be severe, the use of a fungicide should be profitable. Since only the older leaves of carrot are susceptible to blight, fungicidal protection of the new growth is less important than in the case of most crops which are sprayed. The application of Bordeaux mixture, on the main crop sown early in June, need not begin before the first week in August in Massachusetts, and later applications need be made only often enough to replace the copper which is lost by weathering, which means usually at intervals of ten days or two weeks. For carrots sown early in May, treatments should begin early in July.

A horse-drawn sprayer naturally cannot be used in such a closely planted crop as carrots. A small compressed-air sprayer lacks in both capacity and pressure. There have recently become available several types of power sprayers designed for or adapted to use on closely planted crops such as carrots. In the absence of such equipment, a hand duster seems to be the only feasible alternative, although the effectiveness of a copper-lime dust for the protection of carrots against blight in years when the disease is severe has not been determined.

Effect of Time of Planting

Because of the relation which was discovered between the age of carrot leaves and their susceptibility to blight, a field experiment was conducted in 1925 with the object of determining the relation of date of planting to the time of the first appearance of blight. This happened to be a season of but little blight.

Carrots were sowed April 17, May 5, May 22, and June 11. All were harvested October 15 and 16.

During August, the blight was more conspicuous on the early sowed carrots, those sowed April 17 and May 5, then on those sowed later. The development of the disease was clearly associated with the approaching maturity of the carrots. A few weeks before harvest, however, blight, although mild, was uniformly present in all plots. Delay in planting postponed the date of the first appearance of blight, but, when measured by the stage of growth of the carrots, the time of onset of the disease was practically the same in all plots.

The disease appeared relatively late in the growth of each plot of carrots, when the roots were already well grown, and no measurable reduction in yield resulted from blight.

At harvest time, the average weight per root of the carrots sown on each of the several dates was obtained. In the absence of a severe infection of blight, the weights of the roots were affected more by the length of the growing period. The best carrots, considering both size and quality, were those planted May 22. When both the optimum length of the growing period and the relation of age of leaves to susceptibility to blight are taken into consideration, it is probable that, for the late crop, carrots sowed about the last of May or first of June in Massachusetts will do best.

Relation of Fertilizers to Blight

This experiment was undertaken with the object of learning whether or not increasing the amount of nitrogenous or other fertilizer results in an increase in yield of carrots by stimulating blighting plants to the growth of new, and consequently resistant, foliage.

A complete fertilizer, of a 5-8-7 formula, was applied to all plots (0.01 acre in area and in duplicate) at the rate of 1000 pounds per acre before seed was sowed. Other fertilizers, in the amounts per acre named below, were applied as side dressings when the tops were about five inches high.

Blight was only mild and there were no visible differences in growth of tops or in degree of blight infection in the several plots.

The carrots were harvested and weighed at the end of the season. The yields per unit area, expressed as relative numbers, with 100 as an index of the yield on plots which received no side dressings of additional fertilizer, were as follows: with 275 pounds nitrate of soda, yield 106; with 500 pounds acid phosphate, yield 102; with 140 pounds sulfate of potash, yield, 96.

The differences in yields are too small to be significant. In the absence of sufficient blight for the original purpose of the experiment, the effect of the disease on yield was not influenced by the fertilizers.

Control Measures

Since these fungi pass the winter in and on the soil in the refuse of the preceding crop, the possibility of partial control by crop rotation and by deeply plowing under or destroying the blighted tops after harvest is suggested.

Wild carrots should not be allowed to become common near fields where carrots are to be grown, for the fungi which cause blight and leaf-spot are present on these weeds.

There is no reason to disinfect carrot seeds to prevent these diseases.

Carrots planted as late as will permit them to reach marketable maturity are not likely to be affected by blight as severely as carrots planted earlier.

These diseases have not often been severe enough in Massachusetts to make the use of fungicides profitable. It is not recommended that carrot growers here make a general practice of spraying or dusting carrots. If there is continued rainy weather and the grower desires to spray for the protection of carrots, he should use Bordeaux mixtures of the usual formula or dust with a standard copper-lime dust such as is used on celery, beginning about August 15 and making applications at such intervals as are necessary to replace the material which has been washed off the older leaves.

Summary

Blight of carrots, caused by *Macrosporium carotae,* and leaf-spot of carrots, caused by *Cercospora apii carotae,* usually occur together in Massachusetts. Blight is the more important here.

These diseases usually cause no measurable loss on carrots pulled young to be marketed in bunches. On late carrots, they cause no appreciable loss in yield in dry summers and moderate to heavy loss in yield in rainy summers.

Factors affecting spore germination and infection are considered. In Massachusetts, summer temperature is a less important factor influencing development of these diseases than moisture.

The oldest leaves of carrot have been found to be most susceptible to blight.

It has been found that both fungi pass the winter on dead leaves of carrots in or on the soil. No evidence has been found that either of these fungi is carried on the seeds of carrots.

Both fungi are very susceptible to the fungicidal action of copper. Laboratory and field experiments with fungicides are described. It is not recommended that carrots be generally sprayed in Massachusetts, but in rainy summers when blight was severe increases in yield resulted from spraying with Bordeaux mixture.

The latest sowings of carrots are least affected by blight because of the relative resistance to infection of younger leaves, and unfavorable temperatures prevailing late in the growth of the crop.

Literature Cited

1. Clayton, E. E. Carrot rot information. Market Growers' Jour. 38: 15. 1926.
2. Chupp, Charles. Macrosporium leaf-blight of carrot, *in* Manual of vegetable-garden diseases. New York. 1925.
3. Passerini, Giovanni. *Cercospora apii* var. *carotae* Atti, R. Accademi dei Lincei. Anno 286. Memorie della Classe di Scienze Fisiche, Matemiche e Naturali. Serie 4, vol. 6, p. 469. 1889.
4. Ellis, J. B. and A. B. Langlois. *Macrosporium carotae, in* New species of Louisiana fungi. Jour. Mycology 6: 35-37. 1890.
5. Klotz, L. J. Studies on Michigan celery diseases, 2. A study of the early blight fungus, *Cercospora apii* Fres. Mich. Agr. Expt. Sta. Tech. Bul. 63. 1923.
6. Reddick, Donald and Errett Wallace. On a laboratory method of determining the fungicidal value of a spray mixture or solution. Science 31. 798. 1910.
7. Doran, William L. Laboratory studies of the toxicity of some sulphur fungicides. N. H. Agr. Expt. Sta. Tech. Bul. 19. 1922.

Publication of this document approved by the
Commission on Administration and Finance.

4 M-10-28. No. 3638

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 246 OCTOBER, 1928

Control of Red Spider and Powdery Mildew on Greenhouse Cucumbers

By W. D. Whitcomb and E. F. Guba

Contribution from the
Market Garden Field Station
of the
Massachusetts Agricultural College
Cedar Hill, Waltham

Large losses in yield and quality of greenhouse cucumbers result from the attacks of red spider and powdery mildew and from failure to use effective control measures promptly and correctly. Satisfactory treatments for controlling these pests individually are now available but the materials which are used cannot be combined or applied closely following one another with safety. The incompatibility of these materials is a serious handicap to the successful control of these pests when both are present on the vines. This bulletin suggests the proper choice of materials for effective and safe control by a combination treatment, as well as methods of greenhouse management which tend to check the damage by red spider and powdery mildew.

Requests for Bulletins should be addressed to the

AGRICULTURAL EXPERIMENT STATION,
AMHERST, MASS.

CONTROL OF RED SPIDER AND POWDERY MILDEW ON GREENHOUSE CUCUMBERS[1]

By W. D. Whitcomb, Assistant Research Professor of Entomology
and
E. F. Guba, Assistant Research Professor of Botany

Introduction

The red spider[2], sometimes called the greenhouse mite, and powdery mildew[3] are common pests of greenhouse cucumbers in Massachusetts. Few growers in this state can boast that they have grown this crop for two successive seasons without suffering damage from one or both of them. In 1917 it was estimated by Vinal[4] that the red spider caused annual losses amounting to $150,000 in the Boston market gardening district alone. Powdery mildew is often equally serious and its presence at times has proved an important obstacle in the profitable production of greenhouse cucumbers. The presence of both pests on the vines at the same time is common and the need for a combined treatment is obvious. Likewise, a knowledge of the compatibility of insecticides and fungicides used in the greenhouse for combating these and other pests is extremely important to prevent injury to the vines.

Host Plants

The cucumber, especially when grown in the greenhouse, is one of the favorite host plants of both red spider and powdery mildew. Greenhouse tomatoes are also attacked by this mite although they are seldom seriously injured. The red spider also feeds on a great many greenhouse flowers, especially violets, carnations, chrysanthemums and sweet peas. The list of outdoor plants known to be infested by it includes about two hundred wild and cultivated plants ranging from arbor vitae to chickweed.

Cucumber powdery mildew occurs on squash, pumpkin, melon, and other cultivated plants of the gourd family as well as the wild balsam-apple and the bur cucumber. It is also definitely known to attack plantain and sunflower. The common powdery mildews on other plants such as lilac, rose and clover, although similar in general appearance, are different from cucumber powdery mildew and cannot live on plants of the gourd family.

Description and Growth

Effective control of plant pests demands not only the application of specific treatments but also the adaptation of those treatments to local and sometimes varied conditions. This can be satisfactorily accomplished only by a knowledge of the appearance, growth, and habits of the pest and an understanding of the conditions under which it thrives.

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[1] The information in this bulletin is based on the results of experiments conducted by the writers at the Market Garden Field Station, Waltham and in commercial greenhouses in eastern Massachusetts.

[2] *Tetranychus telarius* Linn. (Syn. *T. bimaculatus* Harvey). The red spider belongs to a group of Spiders called *Mites*.

[3] *Erysiphe cichoracearum* DC.

[4] Vinal, Stuart C., The Greenhouse Red Spider Attacking Cucumbers and Methods for Its Control. Mass. Agr. Expt. Sta. Bul. 179, 1917.

Greenhouse red spiders live almost entirely on the under side of leaves where each female lays about 70 spherical, pearly white eggs (Plate I,a1) which are so small that they are scarcely visible to the naked eye. These eggs gradually turn to a dark straw color and in four or five days a round, colorless, six-legged spider larva hatches from each of them (Plate I,a2). After feeding for one to three days, the young red spider, now light green in color with bright carmine eyes, attaches itself to the leaf for a rest and transformation period. While in this condition it appears to be dead but in about 24 hours an eight-legged spider nymph emerges from the old skin and thereafter it always has eight legs. Following each of these molts, as they are called, it feeds ravenously and inflicts the greatest damage by piercing the leaf cells and sucking the green matter from them, thus causing the characteristic yellow or dead areas. Female spiders repeat this process of growth twice before the adult, about one-third the size of a pin head, develops (Plate I,a3). The adults are usually green or yellowish red in color but occasionally rusty red specimens are seen. The smaller, thinner, male red spiders have but two of these transformation periods.

As soon as the mites become established they spin silken webs over the parts of the leaf where they are feeding and in severe infestations these webs extend from leaf to leaf and to the supporting wires or trellises. The average time required for the growth of female red spiders from the laying of the egg to the development of the adult is eight to ten days and for the males seven to nine days. Reproduction is practically continuous in the greenhouse, and in the South at least seventeen generations in one year have been observed out-of-doors.

Cucumber powdery mildew is a parasitic fungus. Such a fungus is a simple plant, in some respects similar to green plants but differing largely in that it maintains a dependent existence as a parasite on green plants. The white powdery webs (plate I,b) on the leaves and young stems, which suggest the name, consist of a dense network of tiny threads from which arise simple stalks each bearing a chain of spores or reproductive bodies. Except for the short, swollen tubes or "suckers" which penetrate the surface cells of the leaf to attach the fungus and to absorb food and moisture, mildew grows entirely on the surface and all visible signs of it may readily be rubbed away with the fingers. When the spores are mature they are shed from the stalks, and drafts of air or slight disturbances to the vines free them from the leaves. Those that fall on cucumber or other host plants germinate under favorable conditions producing suckers and a dense thread-like web bearing a new supply of spores. The multiplication of the fungus in this manner causes a rapid spread of the disease. Mildew weakens or stunts the plants and a severe attack reduces the yield and quality of the fruit.

Most powdery mildews produce winter spores in small black capsules late in the season but very little is known of this stage of cucumber powdery mildew. It is believed, however, that the fungus lives through the winter out-of-doors in this form and also as mycelium or spawn. In the greenhouse the fungus survives from one crop of cucumbers to the next.

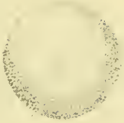
Cucumber powdery mildew should not be confused with the more serious downy mildew which forms a brown web on the under side of cucumber leaves causing yellowish spots and later dead leaves. This disease appears in the late summer and autumn months and because its attack is sudden and its spread rapid, it is much more dreaded by growers than powdery mildew.

PLATE 1.

a. Stages of the Red Spider *(Tetranychus telarius* Linn. syn. *T. bimaculatus* Harvey). (1) Egg. (2) Newly hatched larva having six eggs. (3) Adult female. All highly magnified. (After McGregor, Bulletin No. 416, U. S. Dept. of Agr.)

b. Powdery Mildew *(Erysiphe cichoracearum* DC.) on leaf of cucumber, showing characteristic white powdery growth. About one-half natural size.

a 1



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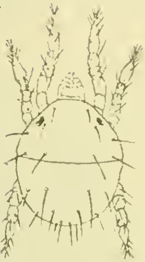
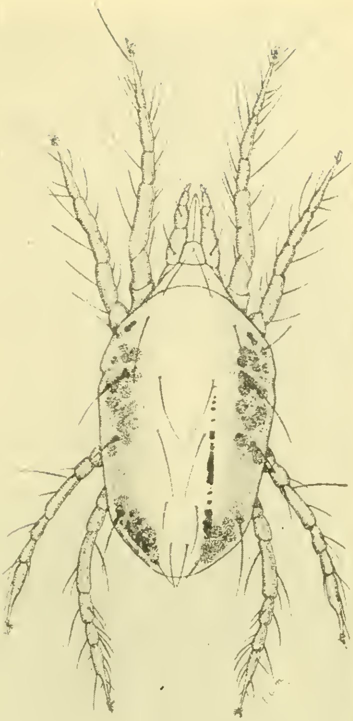
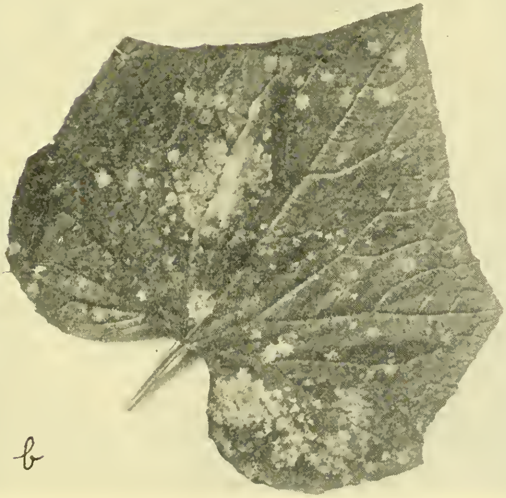




a 3



b

Favorable Conditions for Growth and Spread of the Pests.

Conditions suitable for growing greenhouse cucumbers are generally favorable for the growth and reproduction of the red spider. Its natural migration from leaf to leaf and from plant to plant in search for food, thus increasing the size of the original infested area, is normally very slow but in hot, dry weather when multiplication takes place rapidly, colonies will quickly outgrow the leaves on which they are feeding and spread to surrounding plants. Artificial dispersion resulting in the sudden appearance of isolated colonies, remote from the original infestation, is much more important. Workmen engaged in pruning, training, picking, and otherwise caring for the vines, carry the spiders on their tools and clothing from one plant to another and are the commonest agency responsible for the unnatural spread of this pest. In the summer, however, many of them gain entrance to the greenhouse by being blown through open ventilators or carried on clothing from infested out-door plants growing nearby.

When powdery mildew once appears in the greenhouse its spread may be rapid. The light spores are readily carried by currents of air. The workers become sprinkled with them, especially when brushing against mildewed vines, and are therefore a common means of spreading the fungus from one plant to another and from house to house. Spores from out-door hosts are also a common and important source of infection of the housed plants.

Spore germination and infection occur in damp air. The appearance of powdery mildew in the houses is associated with cool, dull, or damp weather when pipe heat is used sparingly or not at all. Powdery mildew may develop in any season of the year providing favorable moisture conditions prevail. Outbreaks of the fungus accompany improper watering practices and lack of attention to ventilation; drafts of cool or damp air through ventilators, doors, and broken glass; stuffy air pockets not adequately provided with ventilation; and lack of sufficient heat. In every instance moist air, not properly altered by ventilation or heat, is the basis of growth and development. Potted plants when grown under any of the above conditions become mildewed.

Control.

Repressive Measures for Red Spider and Powdery Mildew.

Between-crop Treatment of Greenhouses.

In order to grow healthy plants the greenhouse must be free from parasites which affect those plants before the new crop is set. This is true in the case of red spider when cucumbers or other host plants follow cucumbers but in the case of powdery mildew, only when cucumbers follow cucumbers, since this is the only host plant grown commercially under glass in Massachusetts. If the previous crop was attacked, between-crop-treatment is necessary and in any case it is advisable. By treating the greenhouse before the old vines are removed, the pests are killed without danger of spreading them beyond the effect of the treatment.

The commonest effective treatment is to burn sulfur at the rate of one-third of a pound for each 1000 cubic feet of space with the ventilators closed for at least 24 hours. The fumes from burning sulfur are deadly to plant and animal life. Some growers object to the practice of burning sulfur between crops because of the corroding action which the acid fumes of sulfur have on unprotected metal pipes, posts, and wires, and its bleaching action on paint. It has been common experience that these objections hold only where repeated excessive quantities of sulfur are burned. Many experiments have shown that the fumes from burned sulfur kill all stages of the red spider but in spite of this fact many growers report negative results. These are undoubtedly due to leakage and to the ability of some of the mites to escape the fumes by crawling into cracks where they obtain a draft of fresh air. The practice, nevertheless, is considered worth while as a means of destroying parasites and safeguarding the next crop from a potential inside source of attack.

If the burned sulfur treatment is undesirable, fumigation with calcium cyanide at the rate of one-fourth to one-half pound per thousand cubic feet for 24 hours will kill all red spiders and insects but not mildew. The smaller dosage is sufficient in a gas tight compartment but most greenhouses require the larger amount. After watering freely to provide moisture for the rapid generation of the hydrocyanic acid gas, the calcium cyanide should be scattered evenly over the beds and walks. The fumes are very poisonous and breathing them must be avoided as much as possible. When using cyanide in a large house, it is well for two men to work together, one working toward each end from the center. This treatment is effective, easily applied, and requires no equipment.

When properly carried out, fumigation with melted and vaporized naphthalene rids the house of red spiders and insect pests more effectively than the burned sulfur treatment. The naphthalene crystals are melted and vaporized in shallow pans or dishes over a lamp or kerosene stove at the rate of 1 pound for each 1000 cubic feet. During this treatment, the temperature must be maintained continuously at about 75°F. A stove or lamp for each 10,000 cubic feet is desirable and the heat from the stoves should be regulated so that the melted naphthalene is vaporized without boiling. This fumigation must be continued for at least 48 hours and naphthalene should be added at regular intervals until the required amount is used. This treatment is used generally in England where special stoves for this purpose are manufactured. It requires special equipment and moderate attention. The naphthalene costs about 17 cents per pound and is about as expensive as cyanide in proportion.

The choice of these between-crop fumigation treatments depends largely on conditions. Only burned sulfur exerts fungicidal action, but cyanide and naphthalene are slightly more effective against red spider. Therefore two of the treatments may be advisable.

Hot water or steam treatments of the soil, practiced for controlling soil inhabiting pests in the greenhouse, will kill red spider and powdery mildew present on the treated soil but have no controlling effect elsewhere in the house. Soil sterilizing practices, therefore, should be preceded or followed by fumigation with one or more of the other suggested materials.

Growing Clean Plants

Frequent inspection of the young plants in the plant house is necessary to safeguard against an early infestation. If pests are present, the plants should be given the recommended control treatments immediately. Before the plants are set in the houses, they should again be carefully examined. When either red spiders or powdery mildew are found at this time, control measures should be applied before transplanting. Only pest-free plants should be set.

Precautionary Measures

When either red spider or powdery mildew is discovered on transplanted plants, the recommended control measures should be applied immediately. Since workmen are common means of carrying these pests, it is unwise for those who have come in contact with infested vines to enter other houses without first making every effort to rid their clothing and tools of any pests which may be on them. Picking baskets should be given careful attention. These precautions may appear impractical in commercial establishments but they will aid in reducing the spread and abundance of red spider and powdery mildew.

Mixed Crops in the Greenhouse

Host plants of powdery mildew other than cucumber are seldom grown in the greenhouse, but small lots of miscellaneous plants in benches and pots are often infested with red spider. The origin of serious red spider attacks on cucumbers has been traced to violets, carnations, and mint, and in one case infested chickweed was strongly suspected. Such plants should be examined at regular intervals and if infested, destroyed or treated.

Surrounding Vegetation

The ground immediately surrounding the greenhouse should be kept clean of vegetation or at least free from plants which harbor cucumber pests. It is unwise to grow plants commonly infested by red spider or powdery mildew close to a greenhouse cropped to cucumbers, as any pests present out-doors may be blown or carried by insects into the greenhouse.

Specific Measures for Red Spider Control

Partially Effective Treatments

Spraying and dusting have long been the principal methods of combating the red spider and probably more different materials have been used for this purpose without complete success than for any other greenhouse pest. These materials, if used thoroughly and frequently, when conditions are favorable for their use, will hold a light or moderate infestation in check but the control obtained from them is not permanent and eradication is impossible.

Some of these temporary remedies are washing with water, spraying with salt solution, flour paste, dissolved soap, nicotine, derris extract, pyrethrum extract, pine oil, lemon oil, linseed oil emulsion, miscible oil, and various combinations of these materials. Some check the development of the spiders by washing them from the plants; others stick them to the leaves; and many kill or injure the more susceptible stages of the pest. Some of them are injurious to foliage and none of them give safe and economical control of the red spider on greenhouse cucumbers. Derris extract, pyrethrum extract, lemon oil, and linseed oil emulsion are the best of these partially effective materials, yet each has several disadvantages.

Dusting or spraying with various compounds of sulfur has been used extensively in the past to combat the red spider both in the greenhouse and outside, but the effectiveness of sulfur is limited by its dependence on high temperatures. Sulfur sprays do not kill red spider eggs and have little effect on the transforming stages. Dusting is not effective because of the difficulty in placing the dust on the under side of the leaves where the spiders congregate.

Linseed oil emulsion, developed by Vinal[1], combined a toxic action with the ability to stick the spiders to the leaf when it dried. This spray has been used quite effectively to kill the active and transforming stages of this pest but it has little or no effect on the eggs, and frequently injures cucumber vines.

Highly Refined White Mineral Oil Emulsion

The most effective and satisfactory spraying material for the control of red spider on greenhouse cucumbers is a highly refined white mineral oil emulsion which contains no carbolic or cresylic compounds to aid in emulsification. Experiments with a spray of this type have consistently shown that 95 to 100 per cent of the spiders were killed by one application and that a large percentage of the eggs which were thoroughly wet failed to develop. Two thorough applications gave complete control. It was also observed that many newly-hatched spiders were killed by crawling through the oily spray residue several days after the applications. Many cucumber growers have used this emulsion successfully during the past year in eastern Massachusetts.

This highly refined white mineral oil emulsion is a white, shiny, salve-like material. It should be thinned with a little water before pouring into the sprayer. For spraying cucumbers, a one per cent dilution made by adding 1 gallon of the emulsion to 99 gallons of water, or 1¼ liquid ounces to 1 gallon, should be used. At this strength it does not injure healthy cucumber vines except when applied during temperatures of 95°F., or higher, when burning or a gradual hardening, and yellowing of the older leaves may result. Leaves badly injured by red spiders or other pests may develop this condition more quickly following the use of the emulsion, but this injury is much less than if the pests were not controlled. Cucumber vines have maintained normal growth and fruit production after ten applications of this spray at about weekly intervals without evidence of injury. During the summer the spray should be applied in the evening or during cloudy weather in order that it may dry before being subjected to bright sun and high temperatures. In the cooler seasons it can be used with safety at any time. If cucumber vines are sprayed twice before they are 7 to 8 feet high, little injury by the red spider will follow. In case later sprayings are necessary two applications about one week apart should be sufficient. If small isolated infestations are discovered before the mites have spread, two thorough sprayings of the infested and surrounding area should eradicate the pest and protect the remainder of the vines. Although this spray will control red spider on any plants, its use on other greenhouse plants is advisable only when trials have demonstrated that the plants are not injured. A white mineral oil emulsion can be prepared at home for immediate use but it is recommended that the commercial product now available on the market be used. This product is uniform in quality and the diluted spray costs from 1½ to 3 cents per gallon depending on the quantity purchased.

The spray is best applied as a fine mist which thoroughly wets the vines, especially the under side of the leaves. Knapsack, wheelbarrow, and compressed air sprayers can be used for small areas and young plants, but in spraying a large greenhouse, a power sprayer is desirable. The spray nozzles should be set at an angle of about 60 degrees to the rod.

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[1]. *Loc. cit.*

Fumigation with Naphthalene

In the past, no fumigant has effectively controlled the red spider without injury to the plants. Recently, however, experiments both in Europe and this country have shown that three or four treatments with vaporized naphthalene at the rate of 1½ to 4 ounces of crystals to each 1000 cubic feet were very effective and safe for this purpose with high temperature and humidity. During these experiments, however, it was found that the fruits absorbed the odor and taste of the naphthalene. This almost entirely disappears after several hours in fresh air but the danger of selling tainted fruit to the consumer is considered so important that the treatment is not recommended to cucumber growers.

Specific Measures for Powdery Mildew

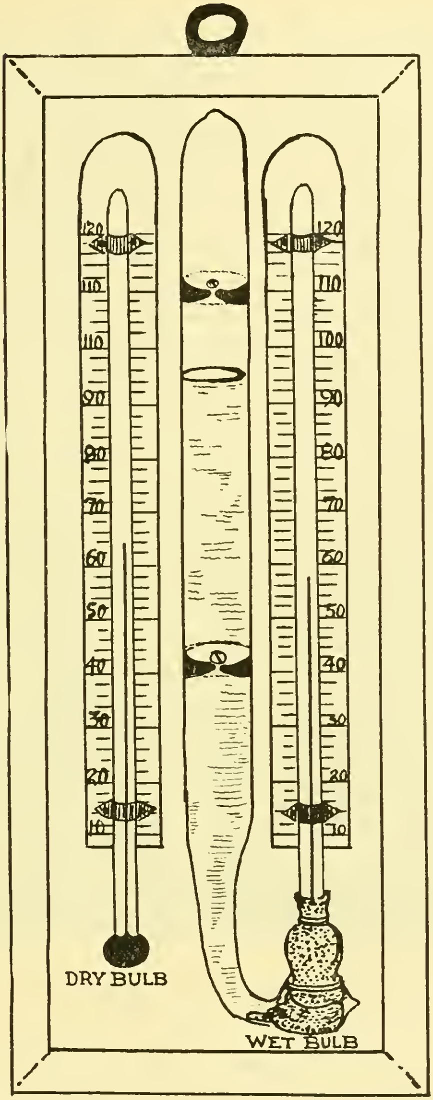
Greenhouse Management

The proper management of the greenhouse air as a means of avoiding attacks of powdery mildew should receive consideration. Healthy plants are never quite as healthy after they have been sprayed or dusted, although the detrimental effect of the materials applied is seldom realized. An atmosphere unfavorable for mildew infection and consistent with the best growth of the plants is the natural method of culture and should supersede the use of fungicides.

Moisture saturated air in the greenhouse is conducive to the development of mildew. The moisture content of the greenhouse air depends on the use of heat and ventilation and may be adjusted to prevent favorable conditions for infection. The relative humidity of the air can be accurately determined only from a hygrometer, a satisfactory and economical type of which is illustrated in Fig. 1. This instrument consists of a dry thermometer, wet thermometer, and glass tube of water for supplying the wet bulb with moisture. The relative humidity is determined by applying the thermometer readings to a simple table. When the air is saturated the temperature of both the wet and dry thermometers is the same. It is desirable to keep the relative humidity of the greenhouse air below 90 per cent. This can be done with heat, ventilation, or both. Side ventilation should not be used at night or during damp weather. If at such times ventilation is desired, it should be from the top and from the side on the top opposite the direction of the wind. Watering should be done on bright days before noon with ventilation and if the air is not sufficiently dry by night, heat should be used. Stuffy air conditions should be corrected by adequate ventilation. Vestibules at the entrances are helpful in preventing conditions favorable for infection of the plants at these places.

Dusting with Sulfur

Sulfur is the most effective fungicide for controlling mildew, and dusting is the most practical and economical method of application. Only sulfur of extreme fineness should be used. Some of the commercial sulfur dusts of this type sold in Massachusetts are Kolo dust, Grape Dust and Tricked Sulfur. The active principle in each of these materials is sulfur but its content varies. Non-dusting sulfur, such as is ordinarily used for burning, lacks the fluffy, powdery qualities of a fine dust, and should not be used for dusting purposes. The desirable grades of dust referred to in this bulletin are prepared especially for dusting plants and may be secured of dealers specializing in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DRY BULB
WET BULB

Fig. 1. A satisfactory type of hygrometer.

the sale of insecticides and fungicides. The choice of any of the materials mentioned should be governed by the retail cost.

The proper choice of equipment for dusting is important. The duster illustrated in Figure 2 has proved most satisfactory for greenhouse purposes. Its use among the plants is not hindered by wires, posts, trellises, or deep walks as is the use of the heavier dusters strapped to the body and provided with long extension tubes. This duster holds 2 quarts or 4 pounds of dust so that the load carried is very light. The dust is expelled by pushing a plunger

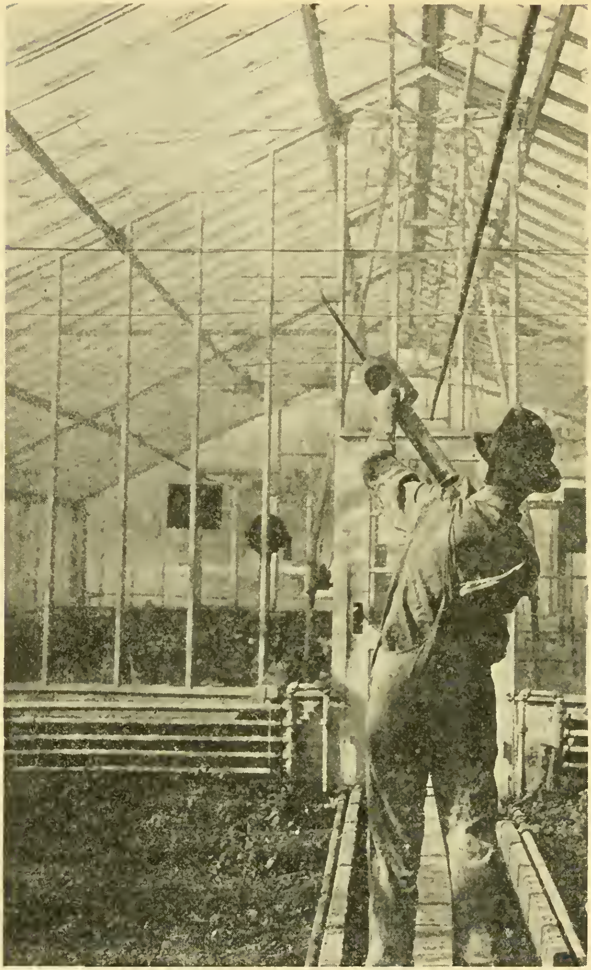

Fig. 2. Type of duster and method of operation recommended for applying sulfur dust to greenhouse cucumbers.

forward with one hand while the other holds the handle supporting the duster.

Quiet air should prevail in the greenhouse to permit the dust to settle. This is obtained by closing all ventilators for 30 to 45 minutes previous to dusting. If closing is likely to cause unfavorable growing temperatures, dusting should be done in the evening or morning when the ventilators may be closed for longer periods thus allowing a more complete settling of the dust.

When dusting, the course of travel should depend on the construction of the greenhouse. In houses 40 feet wide with walks through the center and around the sides, all of the dusting should be done from the walks (Fig. 3,a); in houses wider than 25 feet and provided only with central walk, every 3 to 5 rows should be entered for about one-half the distance (Fig. 3,b). If only outside walks are present the course of travel should be between every

3 to 5 rows of plants (Fig. 3,c). At every 5 to 10 walking paces the extension tube of the duster should be raised overhead. One to two pushes of the plunger with the duster in an obliquely vertical position will cover about 500 square feet with dust. If mildew is encountered on the lower sheltered leaves, light horizontal discharges of dust should be made but the nozzle should never be placed directly upon the leaves. The same general directions apply to a house of young cucumbers. The dust should be directed into the air above the plants and allowed to settle on the foliage. In exercising these precautions the danger of sulfur injury to the vines is reduced to a minimum and there is no waste of material.

The practice of using more sulfur dust than is necessary to control mildew has been responsible for injury. The results of numerous experiments have shown excellent control in 40x280 foot houses from one application with as little as 5 to 6 pounds of dust. More than this amount should not be used even if mildew is generally present in the house. Proportionately smaller quantities should be used in smaller houses. The reasons for suggesting these precautions are (1) powdery mildew is very susceptible to extremely small doses of sulfur under warm air conditions; (2) under similar conditions excessive doses of sulfur cause either burning, hardening or stunting of the leaves; (3) sulfur dusting materials are highly concentrated.

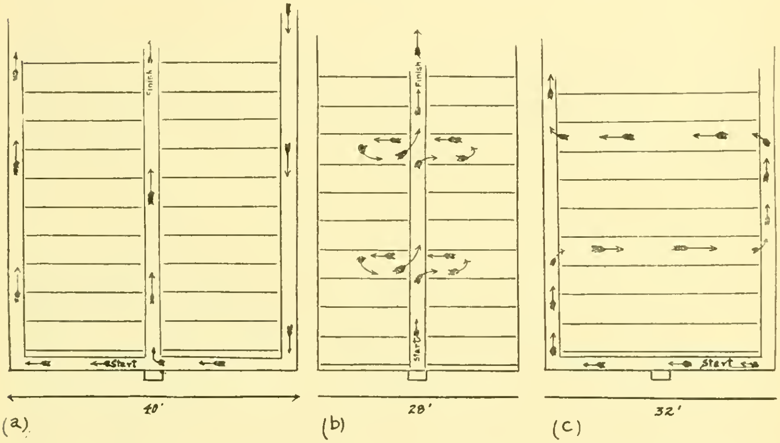

Fig. 3. Courses of travel with duster in differently constructed greenhouses.

The effectiveness of sulfur in controlling mildew is dependent upon sulfur gas which is generated above 70°F., and in increasing amounts with higher temperatures. By proper management of the ventilators, temperatures favorable for the liberal production of gas may be obtained in bright weather. The closing of the ventilators also offers a means of concentrating the gas in the greenhouse. Since the gas given off from sulfur is fungicidal, contact of the sulfur particles with mildew is not necessary, to obtain control. After dusting, the ventilators should be managed, if necessary, to provide temperatures of at least 80 to 85°F., for a few hours each day until the fungus has been eradicated.

Spraying

Below the temperature of 70°F. and in prevailing dull weather, sulfur dusting materials do not give control. Mildew in contact with sulfur particles is destroyed but that on the lower and sheltered parts of leaves is not affected. When such weather conditions render sulfur dust of no value, spraying must be resorted to for controlling the fungus.

Both copper and sulfur spraying materials kill mildew but they are injurious to foliage at strengths ordinarily used on other plants. At weak strengths they impart no harmful effect to the foliage and control mildew. In the case of copper sprays, complete wetting of the foliage is important since the action of the spray is exerted only when the fungus is wetted. After the spray has dried, the copper residue offers little, if any, protection from subsequent infection. Frequent treatments with copper sprays may be necessary to maintain control. Freshly prepared Bordeaux mixture of the formula 1-1-50 or commercial copper preparations diluted to contain an equivalent amount of copper are recommended. Slightly longer protection from infection is provided by sulfur spray residues, of which potassium sulfide made up at the rate of 1 pound to 50 gallons of water is the most satisfactory. Bordeaux 1-1-50 leaves a slight residue which may require wiping the cucumbers before they are packed, while potassium sulfide at the rate recommended leaves none. Aside from this fact the use of either copper or potassium sulfide should be influenced by its compatibility with insecticides recommended for controlling insects and red spider.

Bordeaux mixture should be prepared as follows:

As many pounds of bluestone as there are gallons of water are suspended in a sack in the upper surface of the water in a wooden barrel. When the crystals are completely dissolved each gallon will contain 1 pound of bluestone. Similarly, in a second barrel lump or granulated lime is slaked in water. Slaking should proceed slowly with the addition of water as needed. After the lime is slaked, the container is filled with water so that the mixture contains 1 pound of lime to each gallon of water. Hydrated lime may be substituted if lump lime cannot be obtained. Chemically hydrated lime is considered the best, but if plasterer's or finishing lime is used it should be soaked in water over night. One pound of chemically hydrated lime, or 1⅓ pounds of finishing lime will be required for each gallon of water. In the making of Bordeaux 1-1-50, one gallon of stock lime water is drawn after agitating the mixture thoroughly and poured through a strainer into the spray tank containing 30-40 gallons of water. While the agitator is running, 1 gallon of stock bluestone solution is added. Water is then added to bring the liquid up to 50 gallons. If larger or smaller quantities of spray are desired, proportionate amounts of stock solution must be used. Separate pails should be used for drawing from the stock liquids and a wooden pail should be used for the bluestone. The stock solutions will keep indefinitely but in order that the original concentration of one pound of material to 1 gallon of water is maintained, the barrels should be kept covered.

Commercial copper preparations may be substituted for freshly prepared Bordeaux but they should not be diluted according to directions accompanying the package since these are not applicable to hothouse plants. One pound of bluestone present in Bordeaux 1-1-50 contains about 25 per cent of copper. Each package of copper fungicide bears a statement giving the percentage of copper present in the contents. To determine the amount of material required for making 50 gallons of spray containing as much copper as is present in Bordeaux 1-1-50, divide 25 by the per cent of copper indicated on the package. Thus, if the label reads "Active ingredient—Copper—12.5%", the quantity of that material to use should be 25/12.5 or 2 pounds in 50 gallons of water.

Combination Treatments

The effective control of different pests on cucumber vines may involve the use of several insecticides and fungicides. Alone, these materials can be used with safety but in combination or when following one another at short intervals, some of these same treatments may cause severe injury to the vines.

Under certain conditions, previously discussed, it is advisable to combat cucumber powdery mildew with copper sprays. These sprays leave a copper residue on the leaves which causes severe burning of cucumber foliage when reacted upon by hydrocyanic acid gas generated from sodium or calcium cyanide. Fumigation with this gas for the control of plant lice, thrips, or white fly, therefore, should always be made before spraying with copper fungicides; otherwise these pests should be combated with nicotine fumes or sprays.

The highly refined white mineral oil emulsion which effectively controls the red spider is not so toxic to plant lice and thrips as is desirable. However, concentrated nicotine solutions, the standard insecticides used for the control of these pests, can be safely mixed with it. When lice or thrips are present with red spider, the addition of one pint of 40 per cent nicotine sulfate or 40 per cent free nicotine liquid in 100 gallons of diluted highly refined white mineral oil emulsion, or 1¼ teaspoonful in a gallon, will control all of these pests. In fact, this combination spray is one of the best insecticides known for use on greenhouse cucumber vines.

If, in addition, mildew is present, Bordeaux mixture or other copper sprays may be safely mixed with the oil-nicotine spray or with the oil spray. The addition of Bordeaux mixture to the oil spray greatly improves its wetting and spreading qualities. This is an advantage for controlling both red spider and powdery mildew. A convenient method for mixing this combination spray is to add one-half gallon of the lubricating oil emulsion to the fully diluted copper spray and agitate until the oil is thoroughly dispersed. The nicotine may be added at any time.

When both powdery mildew and red spider are present, the use of highly refined white mineral oil emulsion and a potassium sulfide spray or high grade sulfur dust, as is recommended for the control of these pests specifically, may cause severe injury to cucumber foliage, especially in warm weather. The oil spray makes the foliage more susceptible to sulfur injury and prohibits the use of dusts containing a large amount of free sulfur or sulfur sprays. Experiments with dusts of low free sulfur content have shown that they may be used safely either before or after the oil spray, and, although only mildly fungicidal to mildew, if the sulfur content is 10 per cent or less, they will control the fungus during bright warm weather. In milder weather sulfur dusts containing 15 and 20 per cent free sulfur have given good control. In cool, damp weather when sulfur dust is less effective, and if the use of the oil emulsion is necessary, mildew outbreaks should be suppressed with copper sprays.

Among commercial dusts, Slug Shot, having a free sulfur content of 6 per cent has been found safe for use on cucumbers which have been sprayed with white mineral oil emulsion. This dust contains other active ingredients, which bring the cost up to about 10 cents a pound. A home-made dust of much greater effectiveness and similar safety can be prepared by thoroughly mixing 15 pounds of dusting sulfur with 85 pounds of either 200 mesh gypsum or talc at a cost of about 1¼ cents per pound for materials. The latter dust is preferable, but since a commercial sulfur dust of this composition is not obtainable, its preparation at home is recommended.

Summary of Recommendations.

Learn to recognize the greenhouse red spider, the cucumber powdery mildew, and the injury which they inflict.

Prevent the establishment and spread of these pests by practicing repressive measures.

For red spider, spray with a highly refined white mineral oil emulsion which is free from injurious carbolic or cresylic compounds.

For powdery mildew, practice proper methods of ventilation, watering, and heating, and use small amounts of high grade dusting sulfur. In dull, cool weather or if powdery mildew is troublesome on lower sides of leaves, spray with copper fungicides or potassium sulfide.

When both pests are present, spray with a highly refined white mineral oil emulsion and dust with a low "free sulfur content" dust in bright, warm weather. In dull, cool, weather, or if powdery mildew is troublesome on lower sides of leaves, spray with a copper fungicide combined with highly refined white mineral oil emulsion.

Precautions When Using Insecticides and Fungicides.

Do not fumigate with hydrocyanic acid gas as long as there is residue from copper fungicides on the leaves.

Do not spray with highly refined white mineral oil emulsion while there is residue from high "free sulfur content" dusts on the leaves.

Publication of this document is approved by the
Commission on Administration and Finance
5 M-11-'28. No. 3932.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 247 FEBRUARY, 1929

Biennial Report

For the Fiscal Years Ending Nov. 30, 1927 and 1928

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or printed manuscript.

Requests for Bulletins should be addressed to the

AGRICULTURAL EXPERIMENT STATION,
AMHERST, MASS.

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

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BIENNIAL REPORT OF THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

1927 AND 1928

INTRODUCTION

F. J. Sievers, Director

The last half century has seen vast progress in all lines of industrial development and this applies with special significance to agriculture. Many agricultural practices, still in the experimental stage no more than a few decades ago, are now so commonly accepted that they have been introduced into every day farm use. The more general introduction of scientific methods into various phases of industry for purposes of greater efficiency and service has made necessary pronounced readjustments of formerly well established practices. Such modifications not infrequently result in temporary hardships, the degree of which is more or less proportional to the rapidity with which these adjustments are made. Changes in agricultural practices have been very pronounced since the world war, and the hardships which may be referred to as "growing pains" have been especially evident during these last several years. Drastic readjustments in an industry as decidedly basic as agriculture can not help but be felt in most other activities, and as a result have their effect on the social and economic life of the entire consuming public.

The changes that agriculture has undergone in recent years can be rather definitely associated with some very interesting social and economic adjustments.

They are making it no longer necessary to farm much of the marginal land which in the past, even at its best, was unable to supply more than the bare necessities of life for the immediate farmer and his family.

They are having a pronounced effect on the occupation of the marginal farmer who, due to a lack of interest or ability, is not keeping pace with the new developments and as a result can no longer produce agricultural products at a figure that assures the net profit required for a satisfactory living.

They are releasing for use in other industrial fields a large amount of labor whose service, because of more efficient practice, is no longer required in agricultural production.

They have, because of increased competition, encouraged more thorough consideration of consumer's demand which has resulted in a more adequate supply of high quality agricultural products.

They are making farm life more attractive through the introduction of machinery as a substitute for hand labor, thus eliminating much of the former drudgery.

They are gradually decreasing the destructive competition in agriculture that comes from the farmer who unknowingly produces many products at an actual loss. The greater complexity in the industry today is eliminating the farmer who is not willing or able to keep the required accounts and records showing cost of production.

They are intensifying farm work to the point where it requires less time to perform a day's labor than formerly, thus making farm life more desirable by providing more time for leisure and greater opportunities for recreation.

They are demanding a better equipped and more intelligent rural population because the effective application of modern scientific developments to agricultural practice can utilize to advantage the best preparation that our educational institutions can supply.

Since these and many other changes or transformations in our social and industrial life have taken place during the period that agricultural experiment stations have been in existence, and since these institutions were primarily established to furnish the consuming public with a more abundant and satisfactory supply of life's essentials, it is reasonable that the experiment stations should be given at least a considerable portion of the credit for the results.

That the Massachusetts Agricultural Experiment Station has played a prominent part in this field is evidenced by the results of its findings as published from time to time in bulletins, in scientific and technical journals, and in Director's reports. This report shows the progress made during the last two-year period on those projects that have been actively pursued.

DEPARTMENT OF AGRICULTURAL ECONOMICS

Alexander E. Cance in Charge

Research work in agricultural economics, 1926-28, has been conducted along three general lines, one dealing with the taxation of farm property, one with part-time farming, and the third with economic problems of food production and distribution.

Taxation of Farm Property. (Hubert W. Yount). This project was undertaken to discover the important facts relating to farm taxes and public expenditures in the State. The study was divided into two parts and the first part, relating to assessment practice and taxation problems on the individual farm, was published in 1927 as Bulletin 235, "Farm Taxes and Assessments in Massachusetts". In this study inequalities in assessments were analyzed and certain remedies were proposed.

The second part of the project is an analysis of public expenditures in Massachusetts from 1910 to 1926, showing the increased expenditures for various purposes in towns of different sizes. The increase in rural towns is analyzed in considerable detail. It is intended that this section be published as "The Cost of Government in Massachusetts, with Particular Reference to Small Towns".

Part-Time Farming. (David Rozman). It is intended to investigate the nature of land utilization and agricultural developments in the vicinity of the industrial centers of the State. To obtain an adequate picture of part-time farming, it is proposed to investigate at least three different sections of the State. The survey is already completed in the first area selected for investigation, which included four towns in the vicinity of Lowell. A number of part-time farmers were visited with a detailed questionnaire, taking the history of their occupations, date of settling on the land, extent of farming operations, living conditions, and earnings both on the farm and outside of it. A total of 115 part-time farmers were visited in this district, and the material assembled is now being tabulated.

At present a similar investigation is being carried on in the vicinity of Taunton and Fall River. Before the completion of this project it is planned to investigate also the conditions of part-time farming around Worcester or Fitchburg.

Competitive Factors Influencing the Supply of Market Milk and Cream in Massachusetts. (R. J. McFall[1]). "A Study of the Milk Supply in Massachusetts", published as Bulletin 236, is divided into three sections. The first gives the requirements for the State, and local and outside supplies which meet them. The second, taking Springfield as a typical urban district, shows the amount consumed there, and the area drawn upon to supply this demand. The third discusses the extent to which the milk production of Massachusetts depends upon feed from outside sources.

"Tendencies in Milk Production in Massachusetts," unpublished, includes statistics of the recent changes in numbers of cows, in yield per cow, and in milk production. The industry appears to be on a sound basis. Its greatest development has been in sections of the most dense human farm population.

The Consumer Demand for Apples. (Lorian P. Jefferson). The first part of this project, already published as Bulletin 243, is entitled, "The McIntosh Apple on the New York Market."

The second part of this project considers the demand from the points of view of dealers and consumers, and in relation to prices and wages. This is now ready for publication.

The third section, not yet complete, deals with the competition of apples with other fruits, and between the different varieties of apples.

The Economic Worth of Different Varieties of Apples. (Lorian P. Jefferson). This project has been under way for two years and it is planned to continue it for at least two years more. It looks to obtain definite information as to which varieties are most profitable for the Massachusetts grower.

The study of eggs and poultry comprises two sections. (1) **The Supply and Market Distribution of Massachusetts Poultry Products.** (Hubert W. Yount). The purpose of this project is to analyze the amount and quality of Massachusetts poultry products, the marketing methods used by poultrymen, and the nature and extent of the market demand for local poultry products. Data have been collected to show the relative importance of various marketing methods, together with the principal defects in the methods used. A portion of the material has been summarized in articles for extension use and a general summary is being prepared for publication as a bulletin of the Experiment Station.

A second part of this project is concerned with the **Nature of Consumer Demand for Poultry Products.** (Lorian P. Jefferson). Data are to be collected from retail stores and from consumers in order better to understand consumers' buying habits.

(2) **Prices of Eggs and Poultry Products.** (Hubert W. Yount). This project is subdivided into three parts. One is concerned with the movement of egg prices in Boston and aims to discover normal price movements, the long-time trend, seasonal variation, relations between prices of different grades, relations between farm, wholesale, jobbing and retail prices.

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[1] This project was suspended with the resignation of R. J. McFall. It has now been resumed under the leadership of A. E. Cance.

The second part is a statistical analysis of factors affecting prices, using multiple correlation methods. The relative importance of various supply and demand factors has been determined, both over a period of years, and for different seasons.

The third part of the project is a statistical analysis of the relation between egg quality and price.

Parts one and two have been completed. Part three will be completed in 1929. It is expected that each part will be published separately as an Experiment Station bulletin.

In addition to these organized projects, the department has been concerned with other interested departments in studies defining the present economic position of various farm enterprises in the State. Two of these studies have already been published as extension bulletins, "Potatoes in Massachusetts Farm Economy", and "Dairy Replacements in Massachusetts". Studies are also under way dealing with onions, poultry and certain other aspects of the dairy industry.

DEPARTMENT OF AGRONOMY

A. B. Beaumont in Charge

Tobacco Investigations

Cropping Systems. (J. P. Jones). The outstanding results to date are: (1) the failure of tobacco in rotation with corn and hay, (2) lack of positive benefit from the use of timothy, rye or redtop as cover crops for tobacco, and (3) best yield and quality obtained with tobacco growing every year on the same land.

The Influence of Different Crops on Yield and Quality of Tobacco. (J. P. Jones). Corn and hay have been most detrimental, with potatoes and onions the least. Tobacco after tobacco has been in most cases better than after potatoes and equal to that after onions.

Field Study of Tobacco Production in Massachusetts. (A. B. Beaumont). Data collected from 232 tobacco farms supported findings at the Station relative to soil management and cropping systems. For example, it was found that tobacco grown continuously yielded better than tobacco in rotation, that cover crops were slightly detrimental, and that lime and ashes reduced yields.

The Effects of High Applications of Acid Phosphate on Tobacco. (J. P. Jones). Indications are that, on land growing poor tobacco even though well fertilized, rather heavy applications of acid phosphate will improve the yield and quality of tobacco.

The Amount of Nitrogen Usually Required to Grow Tobacco Successfully. (J. P. Jones). The results indicate that from 150 to 200 pounds of nitrogen per acre are necessary for satisfactory growth of tobacco.

The Form of Nitrogen Which Produces the Best Yield and Quality of Tobacco. (A. B. Beaumont). Results of this investigation to date point strongly to the conclusion that the nitrate form of nitrogen is, among many inorganic and organic forms, the most readily assimilated by, and produces the best quality of Havana tobacco.

The Relation of Form of Nitrogen to Root-rot of Havana Tobacco. (A. B. Beaumont). Evidence thus far secured, not conclusive, indicates that the nitrate form of nitrogen tends to counteract the so-called brown root-rot of Havana tobacco. Ammonium compounds in low concentrations cause a poor root development often accompanied by symptoms similar to brown root-rot.

The Effects of Inorganic and Organic Toxins on Tobacco. (J. P. Jones). Studies thus far have been with aluminum. The results under some conditions have indicated aluminum to be severely toxic, under others less so. More work will be necessary under better controlled conditions before the toxicity of aluminum will be well understood.

Onion Investigations

The Role of Organic Matter in the Production of Onions. (J. P. Jones). The first part of this project has consisted of an effort to grow onions in sand cultures deficient in organic matter. This has not proved possible, and further development of technique will be necessary before definite progress may be reported. The second part of the project has been a study of cover crops for onions. Thus far, no benefit to the onion crop has been shown from the use of either clovers or grasses as a cover crop.

Lime in Relation to Onion Growth. (J. P. Jones). Applications of lime have been shown to increase the yields of onions very markedly on acid soils. Much of the onion land of the Valley has been found to be acid, and upon a soil test, recommendations to apply lime are being made quite generally.

Comparison of Fertilizers Containing Different Amounts of Nitrogen, Phosphoric Acid and Potash for Onions. (J. P. Jones). The outstanding result has been the notable response obtained with the fertilizer relatively high in phosphoric acid and potash—a 4-12-8.

Onion Breeding. (J. P. Jones). Notable differences are already appearing in some of the strains, but the work is too young to report very definite results.

The Cause of a Chlorosis of Corn. (J. P. Jones). The data show quite conclusively that this chlorosis of corn is due to a lack of magnesium. It can be corrected by applications of high magnesian lime and by magnesium sulfate.

The Relative Efficiency of Based and Unbased Sulfate of Ammonia as Carriers of Nitrogen .(A. B. Beaumont). It has been claimed that the mixing of acid phosphate and ammonium sulfate, and the curing of the mixture in storage, a process known to the trade as "basing", produces a product superior to the unbased materials. Extensive pot tests have proved that there is no advantage from this process so far as plant growth is concerned.

Alfalfa Varieties. (A. B. Beaumont). One year's results have shown that certain strains of alfalfa originating in southern climates are not winter-hardy in Massachusetts. Thus far no differences in hardiness attributable to differential fertilizer treatment have been detected.

Ecological Study of Pasture Vegetation. (A. B. Beaumont). Striking changes in the character of pasture vegetation have been secured by top-dressings of lime, superphosphate and muriate of potash. A weedy growth consisting largely of cinquefoil and moss has been replaced with white clover, blue grass and redtop.

The Nitrogen Intake of Certain Grasses and Clovers. (A. B. Beaumont). The purpose of this project is to secure fundamental data on the nutrition of the most common grasses and clovers relative to nitrogen. No conclusive results have been obtained to date.

DEPARTMENT OF BACTERIOLOGY AND PHYSIOLOGY

G. E. Gage in Charge

Nitrogen-Fixation in Relation to Legumes and Non-legumes under Defined Agronomic Conditions. (James E. Fuller[1]). The plan followed has been to study soils of different units to determine the ability of these units to fix atmospheric nitrogen; to isolate organisms from the units and study the distribution of nitrogen-fixing organisms as compared with the nitrogen-fixing power of the soil units; and lastly to study factors which may influence the presence and activity of nitrogen-fixing organisms isolated in these studies.

The units, as suggested above, were obtained by dividing the experimental plot into twenty-four units, so treated as to give the following experimental conditions:

1. Units planted with legumes and receiving fertilizer.
2. Units planted with legumes but not receiving fertilizer.
3. Units receiving fertilizer but not planted with legumes.
4. Units not receiving fertilizer and not planted with legumes.

The fertilizers used were ammonium sulfate, sodium nitrate or dry ground fish.

Each season, after the crops were harvested, nitrogen determinations were made on both soil and crop. It had been expected that units under No. 1 would show the highest nitrogen content, under No. 4 the lowest, and under Nos. 2 and 3 somewhere between. However, the results have been inconsistent. It was assumed from this that the reason might possibly be found by making a biological survey of the plots to determine the possible influence of micoorganisms on the nitrogen content of the soil.

The nitrogen-fixing power of the soil units has been determined. An organism belonging to the genus Azotobacter has been isolated and designated as 9A. It has been found to possess definite nitrogen-fixing power and to be widely distributed in the plot units showing the greatest nitrogen-fixing power. Other organisms have been isolated and studied, among them being several strains of Actinomyces. These Actinomyces exhibit a tendency to use the nitrogen fixed by Azotobacter 9A and other strains of Azotobacter when cultured with them in a synthetic medium.

Studies are now under way to determine whether the nitrogen-fixation in the different soil units is constant and also to establish how uniformly distributed in the units is this new species Azotobacter 9A. Studies are also being made of factors which influence the presence and activity of Azotobacter 9A. These include hydrogen-ion values of the soil, availability of various carbohydrates as sources of energy, and the effect of organic and inorganic compounds.

It is hoped that the data accumulated in this study may furnish the basis of practical methods by which the nitrogen-fixing organisms *naturally present in soil* may be stimulated to greater activity.

Laboratory Service. (Ralph L. France). This service was established July 1, 1928, for the purpose of supplying to the residents of Massachusetts information concerning problems of sanitation and bacteriology; of providing laboratory service for the study and solution of bacteriological problems; and of improving methods of analysis and procedure.

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[1] Mr. Fuller took charge of the work in 1928; previous to that time it was carried on by Dr. Leon A. Bradley.

Practical and theoretical information has been disseminated by letters and directly by personal interviews. Talks and lectures are delivered upon request of organizations and communities. The following types of laboratory service are offered to residents of the state, at cost:

1. Bacteriological analyses of food and food products, milk and milk products, and water.
2. Chemical analyses of milk and water.
3. Preparation and distribution of viable and efficient cultures of nitrogen-fixing bacteria for leguminous crops.
4. Testing of nitrogen-fixing bacteria for quality.
5. Bacteriological examinations concerning sewage disposal.
6. Bacteriological examinations of swimming tank waters for purity.

The Service is but in its infancy. However, during the time of operation some seven hundred examinations have been completed, and the various types of analyses requested to date appear to justify the establishment of the work.

DEPARTMENT OF BOTANY

A. Vincent Osmun in Charge

Tobacco Diseases. (W. L. Doran).

Black Root-Rot. Study of soil reaction in relation to recovery after infestation with Thielavia has been continued on the Tillson Farm plots and in the greenhouse. In 1927, neither tobacco, alfalfa, nor timothy removed enough lime from the soil to increase soil acidity. In 1928, limed plots (lime last applied in 1923) on which timothy or alfalfa had been grown two years were not as acid as similar plots on which tobacco had been grown. Apparently the growing of alfalfa or timothy is not to be regarded as a cure for tobacco "soil sickness" caused by too much lime and resulting in black root-rot.

The soil in limed plots treated with inoculated sulfur or sulfuric and orthophosphoric acids had pH values of 5.6 to 5.8, while limed plots not so treated had pH values of 5.9 to 6.0. The slight increase in soil acidity was sufficient to reduce the infection of Thielavia. Only a trace of black root-rot was found in 1927 on tobacco in limed plots to which acids were applied in two consecutive years. Root-rot was severe on limed plots not acidified.

In 1928, the limed plots had pH values of 6.01 to 6.10, which is favorable to black root-rot; unlimed plots had 5.00 to 5.33, which is too acid for black root-rot. It is evident that the soil made "tobacco sick" with black root-rot because of too generous liming may require as long as six years to return to an acid condition unfavorable to black root-rot.

Temperature tank records in 1926 indicate that in soil with a pH value of 5.9, black root-rot may be severe at soil temperatures below 75°F. Above this temperature black root-rot is not of consequence. In 1927 and 1928, soil temperatures in a limed plot on the Tillson Farm were generally low enough to favor infection of tobacco by Thielavia.

Tobacco on limed soil acidified in two successive years by treatment with sulfur or sulfuric acid and orthophosphoric acid was relatively free from black root-rot. This was true also on limed soil treated with acetic acid, but acetic acid does not permanently change the reaction of the soil and hence the effect would seem to be due to disinfection by the acid rather than to change in the pH value of the soil.

Acetic acid used as a soil disinfectant in tobacco seed-beds infested with Thielavia and "damping-off" fungi has given excellent results. This treatment has been applied to a number of commercial beds and considerable data should be available in 1929.

As a corollary of this feature of the work, acetic acid was tried as a soil disinfectant for the control of damping-off of red pine seedlings in a forest nursery. Very promising results were obtained.

Both monochloracetic acid and formic acid failed to prevent infection of tobacco by Thielavia.

Yield of tobacco on limed plots was much less than on similar plots which had been acidified by either sulfur or sulfuric and orthophosphoric acids.

Phosphoric acid alone was found to favor black root-rot as does lime. Since both of these substances are known to inactivate aluminum in acid soils experiments have been undertaken to determine whether aluminum may be in part responsible for the inhibition of Thielavia in acid soils.

Pot experiments were conducted during the winter of 1926-1927 to determine the effect of lime on tobacco in the absence of Thielavia. Lime in the presence of Thielavia was associated with a loss in yield of tobacco; lime in the absence of Thielavia was associated with a decided gain, which indicates that lime in the absence of Thielavia is beneficial to tobacco.

In experiments conducted to determine the effect of soil temperature on the response of tobacco to lime in the absence of Thielavia, it was found that the greatest benefit from lime was at soil temperatures of 24° to 30°C. At soil temperatures of 20° to 15°C. lime actually retarded growth of tobacco.

On the basis of the sorting record and burn tests of the tobacco grown on the Tillson Farm plots in 1927 it was concluded: that the quality was much poorer on plots with too much lime than on plots with no lime; that the quality on limed plots was improved by the application of acidifying chemicals to the soil; that lime or the absence of lime did not significantly affect fire-holding capacity of the leaf, and that the fire-holding capacity of the leaf from limed plots was improved by certain acidifying treatments of the soil.

No infection of alfalfa by Thielavia was found in limed plots known to be infested with this fungus. Alfalfa does not appear to be a common host of this fungus, and were it not for brown root-rot alfalfa probably could be safely rotated with tobacco. Severe brown root-rot occurred on tobacco which followed alfalfa, timothy, or alsike clover.

Brown Root-Rot. The occurrence of brown root-rot on tobacco grown on soil in which a cover crop of timothy has been turned under and become partially decomposed is a matter of common observation. This suggested a study of the effect on tobacco roots of timothy infusions of different ages applied to the soil.

When such infusions were applied to soil in which tobacco plants were growing, the effect on the tobacco was found to be sometimes harmless and sometimes very injurious depending on the age of the infusions, that is, on the stage of the decomposition of the timothy. The response of plants to an infusion of a given age was influenced by the proportion of tops to roots of timothy used or by the temperature at which the decomposition process went on. These infusions of timothy which retarded the growth of tobacco plants produced on their roots brown discolorations and lesions apparently of the same type as those which, in the field, have given rise to the name brown root-rot. These results lend support to the hypothesis that brown root-rot of tobacco is the expression of the injurious effect on tobacco roots of one or more toxic substances which are formed from, and at certain stages in, the decomposition of vegetable organic matter, more especially the residues of certain slowly decomposing crops such as timothy.

Chemical analyses of timothy infusions prepared at one week intervals were made by Professor Henri D. Haskins. The oldest infusions which in previous experiments were less toxic to tobacco contained the least ammoniacal nitrogen; but the age at which the content of ammoniacal nitrogen was greatest did not exactly coincide with the age at which infusions similarly made were in previous experiments most toxic to tobacco.

Treatment of brown root-rot soil with formaldehyde is known to result in less of the disease on tobacco subsequently grown on such soil. In experiments to test the effect of certain acids on brown root-rot, acetic acid was found to have a like effect.

Neither sulfuric nor nitric acid, in amounts sufficient to lower the pH value of the soil 0.2 to 0.3, had any effect on the brown root-rot of tobacco grown in this soil.

In field experiments on land previously planted to timothy which had been preceded by corn, the yield per acre of cured tobacco leaf was 16 per cent greater in the acetic acid-treated plot than in the untreated check. Orthophosphoric acid gave 17 per cent increase.

In pot experiments, thorough washing or leaching of the soil was followed by some reduction in brown root-rot. But water used in leaching did not induce the disease when used to water tobacco grown in steamed soil.

In the Tillson Farm plots, brown root-rot was severe following alfalfa, timothy and alsike clover in the rotation and the intensity of the disease was approximately the same on limed and unlimed plots.

Control of Diseases of Greenhouse Vegetables. (E. F. Guba, Waltham).

Cladosporium Leaf-Mold of Tomatoes. Fundamental studies in the laboratory have included the action of fungicides on germinating spores, the relation of environment to the epidemiology of the disease and the application of some of the findings to control practices in the greenhouse.

Of the fungicides tested, only vaporized sulfur proved of merit. Successful control both in the laboratory and on spring and fall crops in commercial greenhouses was obtained by vaporizing sulfur at frequent intervals. The utilization of heat in the steam pipes proved impracticable because it is seldom possible to obtain steam pressure sufficiently high to provide the proper temperature for active generation of sulfur vapor. Furthermore, few houses are steam-heated in the early fall and in the absence of artificial heat conditions usually prevail which favor epidemics of leaf-mold. It became necessary, therefore, to devise some other method of vaporizing the sulfur. The need was met by the development of simple electrical apparatus for this purpose and the equipment has been installed and succcessfully used in several commercial houses.

In the study of environmental relations, it was found that spore germination and subsequent vegetative growth of the fungus occur at temperatures from 40° to 95°F. with the optimum at 75° to 80°F. Traces of spore germination were obtained at relative humidities of 98 and 99 per cent, but normal and general germination occurred only in a moisture-saturated atmosphere and water proved to provide the ideal medium.

Germination did not occur at a relative humidity below 98 per cent. In the greenhouse, it was found that a moisture-saturated atmosphere, and especially water of transpiration on the foliage, without adequate ventilation, the use of heat with ventilation, and proper watering to avoid conditions favorable to infection, gave excellent control of the disease. In the spring of 1928, total yields of No. 1 and No. 2 grade tomatoes were increased by 2.83 pounds per plant and the value by 81 cents per plant as a result of these management practices. In the house so managed, 2.08 per cent of the leaflets showed infection as compared with 45.09 per cent in the check house.

A technical paper entitled "Fungicidal Control of Cladosporium Leaf-Mold Disease on Greenhouse Tomatoes" has been prepared for early publication.

Powdery Mildew of Cucumbers. Work on this project has been completed and the results published in Bulletin 246. (See list of publications).

Downy Mildews of Cucumber and Lettuce. (W. L. Doran). Field experiments with sulfur and copper-lime dusts as fungicides for the control of cucumber mildew were conducted in 1927. With 10 applications of copper-lime dust beginning prior to the appearance of the disease, yield of cucumbers was increased 97 per cent over the undusted check, and with 7 applications beginning with the first appearance of the disease, the increase was 54 per cent. Sulfur failed to control the disease and was toxic to the cucumber foliage. In laboratory experiments sulfur was inferior to copper fungicides in preventing infection, but sulfur was more effective than copper in preventing sporulation of the mildew fungus when applied to leaves after inoculation or during the incubation period.

The manner of overwintering of *Pseudoperonospora cubensis* (B. & C.) Rostow. is not known. Cucumber leaves killed by mildew were examined in September but yielded no evidence of oöspore formation. In 1927 and 1928, oöspore-like bodies appeared in the decayed tissues of infected cucumber plants buried over winter in the soil. Failure attended attempts both to germinate these bodies and to obtain infection by inoculating with them.

In the course of this study it has been found that the youngest leaves of cucumber are not susceptible to infection by downy mildew and that this is due, apparently, to two factors: (1) such leaves are wet with difficulty, (2) their stomata are closed.

It was found that in the presence of dew, rain is not necessary for the sporulation of *P. cubensis*, germination of the conidia and infection, but that rain is the most important factor in the rapid dissemination of the fungus.

In the greenhouse, spread of the fungus was completely stopped by removing infected leaves when first seen and by maintaining a low humidity. Work on *Bremia lactucae* Reg., downy mildew of lettuce, has included preliminary studies of host relations, susceptibility of lettuce varieties, longevity of conidia in the soil and spraying of lettuce seedlings for mildew prevention.

Bordeaux mixture proved injurious to seedling lettuce. Its effect on the mildew was not definitely determined because of a low degree of infection.

Conidia of the fungus failed to remain alive in the soil.

Tests with the two varieties grown commercially in Massachusetts, Belmont and May King, revealed Belmont as very susceptible and May King as very resistant to mildew.

On the basis of this finding, Mr. V. A. Tiedjens of the Market Garden Field Station has made crosses of these varieties in an effort to develop a mildew-resistant variety which will head well in winter, poor heading being an objectionable characteristic of May King. At least one promising selection has been made.

Eradication of Nematodes and Parasitic Fungi in Greenhouse Soils. (L. H. Jones). It has been learned through clay pot studies that single applications of calcium cyanide to amounts as high as 9600 pounds per acre are ineffective in eradicating nematodes from a gall-infested soil. However, when the soil is infested with only the motile phase 1200 pounds per acre gives eradication. In an effort to determine the resistant phase, work was centered upon eggs of the "brown cyst" stage. The longest case observed required thirty-nine days for such eggs to hatch. By making three applications each of 1200 pounds per acre at weekly intervals, it was found possible to eradicate nematodes in the soil when all stages were present in galls of a half inch diameter. This method was not successful in the dry hot days of summer.

The problem was then developed on the hypothesis that if the hydrocyanic acid gas, which forms when calcium cyanide reacts with moisture, can be kept in the soil a sufficient length of time the nematodes in all stages will eventually succumb to its lethal character. Investigations conducted in this Department have produced evidence that an acetic acid-treated soil has some properties in common with a soil that has been partially sterilized with steam. Acetic acid alone and in two repeated treatments was ineffective on nematodes. Yet when it was used in conjunction with calcium cyanide complete eradication was secured in two applications, but this combination failed when only one application was made. This method was successful in many experiments and was further developed to reduce labor by dissolving the calcium cyanide in a dilute solution of acetic acid and flooding the soil with the solution. No attempt is made to describe the physical or chemical phenomena involved in the use of these two chemicals for soil disinfecting purposes.

It is felt that further progress on this method may be made by substituting a dry chemical in place of the wet acetic acid. The development of a dry chemical mixture that is effective in nematode eradication would make it possible to eliminate this pest from large areas of land on which the crop production is seriously limited because of this organism.

Two other methods for nematode eradication were attempted. It was found that by keeping the water-holding capacity above 80 per cent the formation of galls on tomato roots could be reduced to almost none. However, the plants do not grow well under such conditions. It was also learned that the nematodes were not destroyed by keeping the soil flooded for a month. This was determined by evaporating some of the water and growing tomato plants under normal soil moisture conditions.

A condition of extreme drought, on the other hand, gives complete eradication. Galls were introduced into air-dry soil. Every half week some pots were removed, watered and tomato seed planted. The nematodes did not survive more than two weeks under these air-dry conditions. If the relative humidity is similar to that of a normal August, then three weeks are necessary. Such an extreme condition of desiccation is not practical for other than potting soils, flats, pots, greenhouse parts, or tools, all of which may be sources of serious contamination.

The Rest Period of Gladiolus. (L. H. Jones.) The particular object in altering the rest-period of gladiolus is to produce out-of-season blooms, particularly for the early winter season. It has been learned that corms may be kept in cold storage during the summer and planted in early October. Thus the rest-period is altered by prolonging it. Though good plants resulted from such stored corms, these plants did not produce blossoms except in instances for which no explanation can be given. Four varieties were planted each with a range of soil temperature from 50° to 95°F. at intervals of five degrees. These soil temperatures were kept constant by automatic temperature tank apparatus. Of the four varieties, (Albania, Arlon, Los Angeles, and Wilbrink) Arlon produced three spikes of blooms. There were four plants at each temperature and each spike of blossoms was at a different temperature. Thus no conclusions can be drawn from soil temperatures in their relation to blooming. The appearance of the plants indicated that the best growth was obtained between the temperatures of 65° and 85°F.

Since soil temperatures had no effect on blossoming, histological study has been made relative to the formation of the floral tissue. The results indicate that in the variety used, Crimson Glow, differentiation occurs and has become prominent at about five weeks from the time the corms are planted. Under natural out-of-door conditions this would be at the time when the daylight is becoming much longer, a fact which may account for lack of blooms when gladiolus is planted in the autumn. Experiments are now under way to ascertain if normal daylight can be supplemented by artificial light in such a way that gladiolus will blossom.

Carnation Blight. (E. F. Guba, Waltham.) Study of Carnation Blight, caused by *Alternaria dianthi* S. & H., has been conducted at the Market Garden Field Station since March, 1928. This disease and red spider are among the most serious obstacles to successful culture of carnations in this State. Frequent syringing of the plants with water as a control measure for red spider is the main factor in the spread of blight in the houses. This danger is removed by the use of vaporized naphthalene for the control of red spider and hence if only blight-free plants are housed, control of blight under glass becomes greatly simplified. It seems evident, therefore, that successful control of blight in the greenhouse depends largely on ability to prevent infection and development of the disease on young plants in the field.

Study of the effect of fungicides on germinating spores at 50° and 90°F. has shown that sulfur dust is not toxic and that copper dust is toxic if moisture is present. Similarly Bordeaux mixtures 2-2-50 and 4-4-50 are toxic to spores in the water drop. The toxicity of copper fungicides is related to the length of time water is present. The lethal action of liquid lime-sulfur in 1-10 and 1-40 dilutions at 90°F. to spores in the water drop is noted, although it is not considered as striking as that of Bordeaux. In general dry lime-sulfur residues are superior to dry Bordeaux residues. This effect of lime-sulfur is most pronounced at higher temperatures. Naphthalene vaporized at the rate of one pound to 5,000 cubic feet, the amount recommended for controlling red spider, exerts no lethal effect upon the spores.

Study has revealed the value of a spreader in preventing foliage infection. Complete foliage covering is provided by the addition of either fish oil or linseed oil at the rate of .3 per cent of the diluted spray.

Eggplant Wilt. (E. F. Guba, Waltham). Wilt of eggplant is caused by the fungus *Verticillium albo-atrum* R. & B. which enters the roots from infested soil. Because of the impracticability of soil disinfection, the problem of control has been approached chiefly from the standpoint of resistance to the disease.

Varieties of eggplants from different parts of the world have been grown to determine their behavior to the pathogene. Numerous types representing a large number of varietal names have been under observation but none has shown evidence of resistance to the disease. Since it is believed that all distinct varieties have been grown and none has proved of any merit for crossing, this phase of the problem has been discontinued.

A paper mulch test conducted this year offered indication of being a means of controlling the disease. Since infection rarely occurs above an average temperature of 77°F., control of the disease by mulching the plants with paper appears promising.

Studies on the relation of soil reaction to infection and growth of eggplants are in progress.

Fungous Parasites of Grasses. (W. H. Davis).

1. *Sclerotium rhizodes* Awd. is the cause of a sclerotial disease which kills the leaves of grasses over large areas in meadows, pastures and lawns. The disease is prevalent in Massachuetts and has been observed in all the New England states. It appears in April and disappears in June of the same year. It reduces the carrying capacity of pastures, cuts the hay yield in meadows as much as 30 per cent and prevents grass plants from maturing seed. The life-history of the fungus has been determined in part and it is hoped that this phase of the study will be completed in the near future.

2. There appear to be two distinctly different diseases, each known as "brown patch", which occur as dead areas in lawns and golf greens. From one of these, which has been designated as "little brown patch", a species of Fusarium has been isolated in five out of seven cases. This Fusarium killed redtop seedlings grown in sterilized compost soil into which the fungus was introduced. Collections of this disease have been made in Massachusetts, Connecticut and New York.

From the second and more common of these diseases, "large brown patch", *Rhizoctonia solani* Kühn has been isolated. Inoculations of grasses with this fungus produced the characteristic disease when atmospheric conditions were "warm and damp." Mercuric compounds controlled the disease.

3. "Snow mold" was observed on lawn grasses about the campus in 1927 and 1928 during the spring; it appeared also on golf greens and fields. In 1927, it appeared first in February and continued until June. The grasses were not seriously injured by it. Eleven specimens, three from New York, one from Connecticut and seven from Massachusetts, showed the fungus to be a species of Fusarium.

4. Striped smut of grasses (*Ustilago striaeformis* (Westd.) Niessl.) has been studied during the last five years. Its life-history has been determined and published. That there are biologic forms of the fungus was indicated by the fact that spores from timothy did not infect redtop, and vice versa. None of the agronomic strains of timothy proved immune to this smut, but some are more resistant than others.

A Leaf-spot Disease of Chinese Cabbage, Caused by an Alternaria. (W. H. Davis.) The disease has been observed each autumn since 1923. Spores measure 5-29 x 7-103 microns as compared with those of *A. brassicae* (Berk.) Sacc. on common cabbage reported as 10-30 x 35-120 microns. However, inoculations indicate that the two fungi are physiologically identical.

Other Activities. In the absence of an Extension specialist in the Department, members of the staff are called upon to render considerable extension service on a variety of subjects coming within the scope of our work. This includes correspondence, response to telephone calls, personal conferences at the offices, a limited number of field visits, lectures on request and the preparation of informational literature. During a year some 500 letters are written, about 100 field visits are made and 250 to 300 persons call at, or telephone to, the offices for help or information. Naturally much time and thought are necessarily diverted by these activities from the main work of the Experiment Station. There is, however, a certain amount of reciprocal benefit to the Station in that the research worker is kept in closer touch and sympathy with the work and problems of the grower and such a relationship is necessarily stimulating and sometimes productive of valuable results. Desirable as such an arrangement may be, it seems evident from the volume of this work that should it materially increase—which appears altogether likely—either the research of the Department must be jeopardized or an addition to the staff would become imperative.

THE CRANBERRY STATION

(East Wareham, Massachusetts)

H. J. Franklin in Charge

The investigation work of the Cranberry Station has made steady, and on the whole, satisfactory progress during the past two years and has unearthed much new and valuable information. The work has been more extensive and intensive than in previous years and has demanded the attention of a somewhat larger number of workers during the active summer season. For this increase of personnel, use has been made mainly of local help but men have been employed in various localities to help in making special weather observations, and Prof. William H. Sawyer of Bates College, who has been on leave of absence and doing post-graduate work at the Laboratories of Cryptogamic Botany at Harvard University, has made the study of a disease often epidemic on the black-headed fireworm his principal thesis work. He has carried on this work actively at the Cranberry Station during the summer season.

The cranberry extension work has increased steadily and is now interfering seriously with the proper execution of research work. This condition should somehow be relieved in the near future.

The research work done at the Station during the biennium is classified here under proper headings, the first four headings being those of the officially approved projects:

Injurious and Beneficial Insects Affecting the Cranberry. (H. J. Franklin.) During the two years a great amount of scattered research work necessary to round out information already at hand was done in order to complete our knowledge of the insects discussed in Bulletin No. 239 published in 1928. The researches of special importance and interest may be discussed under the following headings:

(a) *Disease of the Black-headed Fireworm* (*Rhopobota vacciniana* (Pack)). The work on this disease was done by Prof. William H. Sawyer already mentioned. He determined this disease to be caused by *Entomophthora sphaerosperma* Fres. He found that this fungus is absent or inactive on the bogs where fireworm infestations are notably resistant to control and generally abundant on other infested areas. He found further that bogs on which it is scarce are generally large well managed areas that have been flooded, sprayed and resanded regularly. Evidently, it is killed out directly or indirectly by late spring or summer flooding or by sanding or spraying, for no evidence was found that fall flooding or the winter flood, even when it is held late, affects it.

(b) *Pyrethum Soap Spray.* Extensive spraying tests were carried out with this material to determine its effectiveness as a control for various cranberry pests. As a general result of these tests, it has been decided that the pyrethrum spray should have an important place in cranberry culture as a treatment for the first brood of the black-headed fireworm and as a control for leafhoppers, but that it will not take the place of nicotine sulfate for most of the other treatments for which that insecticide is used.

(c) *Holly Mite (Paratetranychus ilicis* McGregor). The general life history of this mite was worked out and it was discovered that heavy rains during its active season sometimes very nearly achieve its complete control.

(d) *Cranberry Root Grub (Amphicoma vulpina* Hentz). Progress was made in developing new and more satisfactory methods of applying the sodium cyanide solution used as a control for this pest.

(e) *Cranberry White Grub (Phyllophaga anxia* Lec.) Considerable attention was given to the study of the life history of this species and it was found that it could be controlled best by the treatment used against the cranberry root grub.

(f) *Cranberry Black Bug.* This cranberry pest has not heretofore been recognized in literature but it is often so abundant that it drains the vines seriously. Its life history was partially worked out.

(g) Considerable attention was given to the parasites of cranberry pests and several new forms were reared.

(h) Cranberry flower pollenation and the relationship of insects to it was studied.

Cranberry Disease Work. (H. J. Franklin in cooperation with the Bureau of Plant Industry, U. S. D. A.). Dr. Neil E. Stevens of the Bureau of Plant Industry was at the Cranberry Station during the growing season both years and cooperated very actively in this work. The chief studies were the following:

(a) *False Blossom Disease.* The distribution and spread of this disease and the possible relationships of insects and of flooding to it were given very extensive and careful attention. The McFarlin variety was found to be the most immune of all the cultivated varieties and the Early Black variety is generally only moderately affected by it. On the other hand, the Howes variety, which is the standard late variety, is very susceptible to its attack. This disease has been spreading rapidly in recent years and has become a major cranberry problem. Its effect on the Howes variety is so great that the discovery of a new late variety resistant to it may soon become imperatively necessary. It was found that this disease originated with the cranberry in Wisconsin and was brought from Wisconsin to Massachusetts and New Jersey in diseased vines. Its lines of spread in this State from one bog to another were traced, in some cases through considerable series of bogs. It seems probable that this disease originally affected some other species of plant, probably a plant introduced from abroad and grown extensively in the Middle West and not very much in the East. To discover this other host presents an interesting and probably difficult problem. It was proved experimentally that the disease is carried from diseased to healthy plants by insects and experiments have been started to determine just what species are the carriers. Experiments were also started to determine whether the disease can be carried merely by contact. As it was found that nearly all the serious cases of infection by this disease are on bogs that are flooded but little during the growing season, members of the Cranberry Station staff have been recommending that late June flooding be practiced to keep down the spread of the disease where water supplies are available, it being believed that flooding at that time destroys the carriers. As the blunt-nosed leafhopper (*Euscelis* spp.) is very commonly associated in abundance with severe attacks of the disease, it is believed that this species may be found to be the principal carrier and for that reason spraying with pyrethrum soap is recommended for treating areas where water supplies for flooding are deficient.

(b) *Relations of Weather to Keeping Quality of the Fruit.* Dr. Stevens has had this study in charge alone. His findings have enabled him to make accurate forecasts of the general keeping quality in recent years.

(c) *Incubator Tests of Keeping Quality.* These tests have been continued and extended so satisfactorily that they probably will eventually be made extensive use of by cranberry selling agencies as a means of determining what disposition to make of shipments.

(d) *Fairy Ring fungus.* Rather extensive studies of this fungus that works in the soil and kills out vines in ever-growing rings were made and considerable information of value regarding it was accumulated.

Weather Observations with Reference to Frost Protection. (H. J. Franklin in cooperation with the U. S. Weather Bureau.)

(a) Reports of local weather observations made at 8 A. M. (eastern standard time) were made daily by telegraph to the office of the Weather Bureau at Boston. General weather observations were made and recorded at 8 A. M., Noon and 8 P. M. in 1928.

(b) Further weather records likely to have a bearing on cranberry frosts were accumulated in both 1927 and 1928, several new observers at selected points in Barnstable, Plymouth and Middlesex counties assisting in this.

(c) Studies of observations already recorded were made from time to time, these resulting in a constant increase in our knowledge of these problems and a correspondingly greater ability to forecast minimum bog temperatures accurately. The most recent result of these studies is the discovery that wet bulb observations made at East Wareham, South Chelmsford and Worcester are more valuable as a basis for reckoning minimum bog temperatures in the early evening than are the bog temperature and dew-point observations used heretofore.

(d) Forecasts of minimum bog temperatures were made in the frost seasons of 1927 and 1928 in the early afternoon and the early evening. These forecasts were distributed by the New England Telephone and Telegraph Co., the cost of distribution being paid by the Cape Cod Cranberry Growers' Association as heretofore.

Blueberry Investigations. (H. J. Franklin in cooperation with the Bureau of Plant Industry.) The Station blueberry patch has been used mainly as a demonstration plantation. Not much investigation work has been done in connection with it. The most interesting development was the satisfactory demonstration of the practicability of inter-planting young blueberry patches with Howard No. 17 strawberries. Experience thus far indicates that the cheap weed control and the humus added to the blueberry soil by the mulching of the strawberry vines are of very material value.

In addition to the work of the listed projects of the cranberry station, important investigations were conducted along the following lines:

1. **Weeds.** Spraying with a pound of slacked lime to two gallons of water proved to be a valuable new control for green moss. This kills the moss almost completely at a cost of about ten dollars an acre. It should be put on in late October or early November.

2. **The Relationship of Weather to Cranberry Productiveness.** The studies so far made show that warm sunny weather is essential to the proper preparation of cranberry vines for maximum productiveness and suggest that other fruit plants such as apple, pear, swamp blueberry, wild black cherry and beach plum are in general affected in the same way. They also indicate that the size of general cranberry crops can be predicted to a considerable extent.

3. **Varieties.** The more noticeable characteristics of practically all the varieties of cranberries grown have been studied and compared for the purpose not only of developing and systematizing knowledge of the varieties but also of laying down lines of correlation for guidance in making future selections from the wild. As a result of this work, it has been found that color of foliage, average seed count, and fruit bloom are correlated with varietal productiveness and disease resistance.

A series of analyses made by Prof. F. W. Morse show clearly that the varieties that are in general the most resistant to disease have the highest percentages of total acids in the fruit.

DEPARTMENT OF DAIRY MANUFACTURES

J. H. Frandsen in Charge

Washing Powders for Dairy Use. (A. W. Phillips[1]). Work on this project has been completed and the results published as Technical Bulletin 13. (See list of Publications).

The Quinhydrone Electrode in the Dairy Laboratory. (K. E. Wright[2]). Work on this project up to this time can be summarized as follows: The quinhydrone electrode determination of pH cannot be used as a method for determining the keeping quality of milk. Either the quinhydrone method for pH determination cannot be applied to milk, or the pH of milk gives no indication of its keeping quality. The latter reason seems the more probable. Further work on this project is under way.

A Study of Packaged Ice Cream. (K. E. Wright). This study has been confined to the two major objections to the rapid adoption of the factory filled package: namely, the light weight and poor texture. It has been found that:

1. A twelve-ounce pint package made by drawing at an overrun of 50 per cent is an ideal weight to meet the objections of the light weight package.

2. A 12 per cent fat, 10 per cent serum solids, 15 per cent sugar, and 35 per cent gelatine product should be drawn at a temperature not over 25½°F. to avoid coarse texture.

3. An increase in fat content of 2 per cent helped to satisfy the requirements for food value lacking in the lighter package. Higher fat also appreciably improved the texture.

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[1] After the resignation of A. W. Phillips, the material was prepared for publication by J. H. Frandsen and M. J. Mack.

[2] Work on this project was started by A. W. Phillips.

4. The following factors cause a low initial whip which facilitates drawing the product at a temperature low enough to favor smooth texture: increase of fat content, substitution of butter for cream, the addition of .3 per cent egg yolk or of .15 per cent calcium lactate, and the addition of the gelatine after cooling the mix.

5. Sharp scraper blades and a brine temperature below 5°F. were found essential to the proper cooling of ice cream with a low overrun.

Utilization of New England Fruits in Frozen Dairy Products. (M. J. Mack). The fruits used in this project were packed by the Department of Horticultural Manufactures. Approximately 150 gallons of fruit are available, of which ten varieties of strawberries make up at least half. The other fruits are raspberries, cherries, peaches, blueberries and plums.

These fruits are now being utilized in fruit ice creams. Preliminary tests of the flavoring ability of different varieties, optimum amounts to use, ratio of sugar to berries, treatment of the fruit, etc., are now under way. This work will be followed by a careful study of the effect of these fruits on the freezing process and on important properties of the finished ice cream. As yet the work has not advanced to the point where any conclusions can be reached.

DEPARTMENT OF ENTOMOLOGY

H. T. Fernald in Charge

Dates of Hatching of Scale Insects and When to Spray for Them. (A. I. Bourne). With many scale insects the most successful treatment should immediately follow hatching of the eggs. To determine when this time comes sufficiently beforehand to be prepared for treatment at the right time is a great advantage. Data for many years have been collected and compared with temperatures from the time of egg laying through hatching, in an attempt to determine the total accumulated temperature to bring this about. Abnormal seasons, as they have occurred, have also been studied and the investigation is now well in hand.

Investigation of Materials which Promise Value in Insect Control. (H. T. Fernald and A. I. Bourne). Four different types of miscible oils, four "soapless" emulsions and one lubricating oil emulsion have been tested for efficiency as insecticides and safety to trees, all but one of these being now on Massachusetts markets or about to be placed there.

The miscible oils and lubricating oil emulsion gave satisfactory control against the European red mite, with the "soapless" emulsions less effective, one of these last being so toxic as to cause serious injury.

Control of Onion Thrips. (A. I. Bourne). An effective spray combination has been developed but dusts have proved ineffective. A schedule of applications has been completed.

As horse-drawn spray machinery cannot be used in the Connecticut Valley onion fields because of cultural methods, a machine to fit these conditions has been produced. It is a power sprayer, both propelling machine and developing pressure for spraying with a compressed air pump. It will sustain a 200-lb. working pressure while covering six rows. Though this outfit has given promising results, premature dying of onions the last two years and light infestation of thrips have prevented large scale tests.

Spray Residue Problem and Its Relation to Orchard Practices. (A. I.

Bourne). Wealthy, McIntosh and Baldwin apple trees have been used to determine the latest date on which lead arsenate could be applied without danger of too great residue. Both 1927 and 1928 had large amounts of rainfall during the summer, and it was found that the Wealthy could be sprayed as late as July 15: the McIntosh during all July; and the Baldwins were under tolerance limits even when sprayed in mid-August.

It is apparent that in dry seasons or with moderate rainfall, present spray practices for later spraying will need modifications. Dust applications show less residue on fruit at harvest than sprays.

Adaptation of the Recommended Spray Schedule for the Control of Orchard Insects to Eastern Massachusetts Conditions. (W. D. Whitcomb). Studies at Waltham show that spraying recommendations based on insect studies of Amherst are generally applicable in eastern Massachusetts. With the apple maggot, however, it was found that during a period of three years the flies did not emerge in sufficient numbers to warrant spraying before July 15, whereas the Amherst recommendations advise spraying by July 1. It has also been found that a spray three weeks after the calyx spray is more effective in combating the plum curculio and codling moth in apples than has been realized hitherto, and that the pink spray has no value against the plum curculio.

Control of the Plum Curculio in Apples. (W. D. Whitcomb, Waltham). Repeated studies now show that the plum curculio is most abundant from June 15 to 22, and that the greatest amount of injury from feeding and egg punctures takes place immediately thereafter; that oviposition ends about July 31 but the feeding punctures continue until cold weather although rather unimportant after August 10. Lead arsenate, 2 lbs. or more in 50 gals. of water, applied seven to ten days, and again three weeks after the calyx spray, seems to be the most effective for material and time. Calcium arsenate and sodium fluosilicate are effective but liable to injure fruit and foliage. Fish oil and molasses each tend to increase the effectiveness of the lead arsenate. Following this treatment, orchard tests have given 91 per cent control as compared with 91 per cent injury on adjacent untreated areas.

Control of Red Spiders on Greenhouse Cucumbers. (W. D. Whitcomb, Waltham). Studies during 1926 and 1927 show that the greenhouse red spider may be effectively controlled in all stages by spraying with highly refined white mineral oil emulsion if no carbolic or cresylic compounds are used in its preparation. It can be applied to greenhouse cucumbers at the rate of 1 part in 99 of water, except when sulfur fungicides are also used.

Red spider is also effectively controlled by three or more fumigations with naphthalene, 1½ to 3 ounces per 1,000 cubic feet, with enough heat to vaporize the material in not less than six hours. During this time the house temperature must be 75°F. or above, and humidity 75 per cent or higher. The cucumbers taste and smell of the naphthalene but, nevertheless, this treatment is being used by market gardeners.

Biology and Control of Garden Cutworms. (W. D. Whitcomb, Waltham). Seventy-three different kinds have been collected or reared. Screen traps have been used very successfully for collecting these insects to provide material for the experiments, and control tests show that a mixture of 25 pounds of bran, 1 pound of Paris green, 1 quart of cheap molasses and 2 gallons of water gives effective control. Sodium fluosilicate and white arsenic prove less effective than Paris green. Applications should be repeated at about ten-day intervals to reach cutworms which migrate to the garden from outside.

Biology and Control of the Carrot Rust Fly. (W. D. Whitcomb, Waltham). The flies winter as pupae in the soil and emerge early in June. Many eggs are laid by the middle of the month, and the larvae are abundant on carrots for about a month thereafter. A second generation produces maggots which attack the carrots from the middle of August to the middle of September. Carrots planted in April or May are severely attacked, but plantings in June are quite free from injury by the first generation of flies.

Against the first generation, asphalt mulch paper, Derris compounds, corrosive sublimate and sodium fluosilicate gave very encouraging results, but proved quite ineffective against the second generation.

DEPARTMENT OF FARM MANAGEMENT

J. A. Foord in Charge

Although some investigational work has always been carried on in the department, and small grants had been made from Experiment Station funds from time to time, the research work has been regularly organized in the department only within the period covered by this report. An Investigator was appointed in January and an Assistant in March 1928, as noted elsewhere.

The first project outlined and approved was on the "Competitive Status of Massachusetts Farm Enterprises" and two bulletins have been published, abstracts of which are given in the List of Publications. With the growth and development of the work it has seemed best to supersede the first project by four others a little more closely in line with the needs as they appear today. These are as follows:

Enterprise Relationships and Farm Organizations on Selected Dairy Farms in Western Massachusetts. (R. L. Mighell and Marian Brown). This project aims to obtain from selected dairy farms basic data both on dairying and on various supplementary enterprises which can be used in planning the most profitable farm organization. Following a study of farm management survey records, and other data, and some field study, approximately 25 farms were chosen in Franklin and Berkshire Counties. Inventories have been taken and records are being kept of essential items of farm business including labor.

The Place of Poultry Production on Massachusetts Farms. (R. L. Mighell and F. H. Branch). Under this project a study and analysis has been made of 400 yearly records of Massachusetts poultry operators collected by the Extension Specialist of the Department in connection with another study. The statistical method was used to determine the important factors affecting profits. The average relationship between variations in annual egg production per bird, diversity of business, rate of flock reduction, price, and fall egg production, and labor return, are being determined by correlation analysis. Publication of results may be expected early in 1929.

Types of Farming in Massachusetts, 1840-1925. (Marian Brown). Most of the census material available for this study has been compiled, together with non-statistical material for several leading farm enterprises.

Factors Responsible for Variations in Physical Production and Economic Costs of Milk in Massachusetts. (R. L. Mighell and Marian Brown). A determination of the influence of different production practices on milk production, and how these practices would need to be changed under changing economic conditions, is the object of this project.

An initial study has been made of Herd Improvement Association records in the State. This will be continued, and further study will be made of the records of the College and Experiment Station Herds.

Other Activities of the Department. Both the Research and Extension Specialists have been members of the College committee on the Economics Status of Massachusetts Agriculture, and in this capacity contributed freely in the publication of Extension leaflet No. 119, Potatoes in Massachusetts Farm Economy (16 pages); and Extension leaflet No. 20, Dairy Replacements in Massachusetts (16 pages). While not under a definite research project these publications called for the collection and interpretation of many data and were published in response to a definite need.

During the last year the Departments of Farm Management and Agricultural Economics have cooperated in starting a monthly publication called "Farm Economic Facts". Although published by the Extension Service, material has been contributed by the Research as well as the Extension Staff.

During the summer of 1928 the department cooperated with the departments of Agronomy and Plant and Animal Chemistry in potato trials on the College Farm covering five different spraying mixtures, and different amounts of seed and fertilizer. The latter was suggested by the findings in the survey work upon which Bulletin 240 was based. The results of the spraying work are being reported by the Department of Plant and Animal Chemistry. Due to soil variations and the unfavorable season, results on seeding and fertilization were inconclusive and the work will be repeated.

FEED CONTROL SERVICE

Philip H. Smith in Charge

The work of Feed Control Service comprises not only feed inspection but several other activities, as listed below:

Feed Control (General Laws, 1920, Chapter 94)
Seed Control (General Laws, 1927, Chapter 94)
Dairy Law (General Laws, 1920, Chapter 94)
Advanced Registry Testing
Miscellaneous work

Feed Control. (P. H. Smith, H. R. DeRose, J. W. Kuzmeski, M. W. Goodwin, F. A. McLaughlin). During 1927, 1602, and 1928, 1600 samples of feeding stuffs were collected and examined in our laboratories. No local prosecutions for violations of the feeding stuffs law were attempted. Acting as Federal inspectors, our agents have drawn about 30 samples of interstate shipments of feeding stuffs which previous analysis had shown to be below guarantee in protein, fat or fiber. These samples are submitted to the Food, Drug and Insecticide Administration Laboratories of the Federal Government who, if action is thought advisable, proceed directly against the manufacturer. It is thought that this is a more satisfactory method of procedure than to prosecute the local dealer who is in all probability selling the goods with the belief that they are as represented.

Seed Control. (O. W. Kelly, C. L. Beane). A new seed law administered by the State Department of Agriculture became effective Nov. 1, 1927. A seed laboratory for the examination of official samples collected by the Department of Agriculture has been established at the Experiment Station. This work also includes the examination of seed samples submitted by seedsmen, farmers, and others, for which a fee sufficient to cover the actual cost is charged. During the present year, in addition to establishing the laboratory there have been examined 80 samples of seeds and seed mixtures for purity, 489 for germination only, and 220 samples for both purity and germination tests. A larger number of samples will be examined in 1929. The first year's work has demonstrated the value of seed inspection service. In addition to the laboratory examinations, field tests have been conducted on clovers and alfalfas by the Department of Agronomy, and upon vegetable seeds by the Market Garden Field Station, in order to determine trueness to type.

Dairy Law. (P. H. Smith, J. T. Howard, H. L. Allen). The work under this law involves:

1. The testing of Babcock glassware for accuracy.

2. The examination and award of certificates of proficiency in the use of the Babcock test to applicants.

3. The annual inspection of creameries, milk depots, and board of health laboratories where the test is used as a basis for fixing the value of milk and cream.

During the two years ending December 1, 1928, 15,253 pieces of Babcock glassware were tested. Condemned bottles amounted to less than one per cent of the total tested. One hundred and forty-four certificates of proficiency were awarded. In 1927, 136 creameries, milk depots, and milk inspectors' laboratories were visited in order to check methods and pass upon equipment in use. This work has not been completed for 1928.

Advanced Registry Testing. (P. H. Smith). The testing of pure bred cows for advanced registry in cooperation with breeders and pure bred cattle associations has been under the direction of Feed Control since its beginning in 1902. For several years the volume of work has not materially changed. The average monthly record shows about eighty farms having cows on test, about 600 cows under test, and from eight to ten supervisors continuously on the road to care for the work. Advanced Registry Testing is supported entirely by the breeders having animals under test. Reimbursement is made not only for the supervisors, but for the office expenses as well.

Miscellaneous Work. (P. H. Smith, H. R. DeRose, J. W. Kuzmeski, M. W. Goodwin). The resources of this department are available for the analysis of milk, cream, and feeding stuffs submitted by farmers and others. For this service a fee is usually charged. A considerable number of analyses are also made for other departments of the College in connection with experimental work. Especial equipment has been installed for drying large samples of forage crops.

Summary of Miscellaneous Work, 1927-1928

Material Sent In

Milk and cream, butter fat only	735
Milk, solids and fat	368
Feeds	221
*Waters	68

For Other Departments of Experiment Station and College

Cucumber leaves from Market Garden Field Station (Starches and sugars)	1 month's work
Moisture tests, Forage Crops	485
Complete fodder analyses	253
Moisture tests and nitrogen	55

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* Work of water analysis turned over to Department of Bacteriology on July 1, 1928.

FERTILIZER CONTROL SERVICE

H. D. Haskins in Charge

Fertilizer Inspection. (H. D. Haskins, H. R. DeRose, M. W. Goodwin, J. W. Kuzmeski). During the season of 1928, 105 manufacturers and their subsidiaries have registered in Massachusetts 610 brands of fertilizer, fertilizing materials and agricultural limes. The following table shows the nature of these materials and the extent to which they have been inspected.

Material	Brands Registered	Brands Collected	Samples Collected	Number of Analyses
Mixed fertilizers	348	324	1015	413
Ground bone, tankage and fish	63	58	149	75
Nitrogen products	78	71	207	126
Phosphoric acid products	29	28	100	40
Potash products	29	25	66	44
Pulverized natural manures	20	20	75	23
Miscellaneous materials	14	15	29	23
Lime products	29	30	66	30
Totals	610	571	1707	804

In the year's inspection, 21,576 sacks were sampled representing 8,601 tons of material; about 300 towns and suburban districts and 900 agents were visited.

From July 1, 1927, to July 1, 1928, the following tonnages of fertilizer and plant food were sold in Massachusetts:

Fertilizer and Plant Food Tonnage

	Tonnage			
		Actual Plant Food		
	According to Type	Nitrogen	Available Phosphoric Acid	Potash
Mixed fertilizers	47,626	1,887	3,688	2,883
Fertilizer chemicals and materials unmixed	19,644	1,177	1,924	667
Pulverized natural manures	3,188	89	54	88
Totals	70,458	3,153	5,666	3,638

Full details of the fertilizer inspection work may be found in Bulletin No. 45, Control Series, published in December, 1928.

Miscellaneous analytical work. (H. D. Haskins, H. R. DeRose, M. W. Goodwin). During the period from November 1, 1927, to April 1, 1928, the usual amount of cooperative chemical work was done on problems of other departments of the institution. Its general nature is shown from the following summary:

29 samples of tobacco stalks, partial ash analysis
3 samples tobacco leaves, for partial ash analysis
30 samples timothy decoction residues: dry matter, ash and nitrogen
36 samples timothy decoction: total, ammoniacal and nitric nitrogen, and testing for organic toxins.
207 samples millet: dry matter and nitrogen
29 samples processed organic ammoniates: total, insoluble, ammoniacal and nitric nitrogen, insoluble nitrogen activity tests, total phosphoric acid.
10 samples timothy cover crop for partial ash analysis

The department has also made the following analyses for institutional departments, farmers, and farm service organizations: fertilizers 42, soils 12, manures 3, lime products 3. For this service, outside of departmental work, the Experiment Station receives compensation.

In addition to this, the department has performed the usual cooperative work with referees of the Association of Official Agricultural Chemists on studying new and existing methods of analysis.

Vegetation Pot Experiment—Season of 1928. (H. D. Haskins and A. B. Beaumont). This experiment, comprising 131 pots, was conducted in the study of the nitrogen availability of low grade organic substances high in nitrogen which have gradually replaced animal tankage and fish, formerly largely used in mixed fertilizers. Results are reported in Control Bulletin 45.

DEPARTMENT OF HOME ECONOMICS RESEARCH

Esther S. Davies in Charge

The Food Consumption of Rural School Children in Relation to Their Health. (E. S. Davies). Work on this project has been completed and the results published as Bulletin 241. (See list of publications).

Present Practices of Massachusetts Elementary Schools with Regard to School Feeding and Transportation and Their Effects upon Health of Pupils. (E. S. Davies and C. B. Church.) In the course of the survey for the preceding project, it became evident that an important factor in the food practices of the children of elementary school age is the type of noon meal; and that the organization of the public schools tends more and more to make it necessary for this noon meal to be eaten at the school house. The consolidation of rural schools, moreover, always involves the transportation of a large proportion of the pupils, which in turn affects the length of time the children must be away from home and raises questions as to the possibility of increased fatigue and exposure; as well as increasing the number of those who must eat the noon meal away from home. It was, therefore, deemed wise to undertake an investigation of the present practices of the schools of the 237 Massachusetts towns of less than 5,000 population, with regard to transportation of elementary school pupils and the facilities provided for food service, in the belief that these have a close relation to the physical welfare of the children.

This study is being pursued by conferences with the superintendents of schools, visits to the teachers at the school houses, and, finally, by personal inspection of food services and actual experience in using the transportation facilities. To supplement the information thus obtained, abstracts are made of the medical examination records in certain towns, to study the comparative physical status of the pupils from year to year. As another angle of approach to the solution of the problem, in a number of representative school rooms, scattered throughout the state, the teachers are keeping detailed records of the duration and real cause of all absences during the current school year.

The field work on this project cannot be completed before the close of the school year next June, but certain tendencies seem clearly defined in the part of the work which has already been finished. The number of schools in which provision is made for year-round serving of a hot food or drink at noon is almost negligible; and the number providing such service during the cold weather is less than half the total number of schools. Mid-morning milk service is practically non-existent.

Transportation is generally provided only along the main highways, the children walking to assembling points. It is the unusual town that provides shelter from the weather at these places where the pupils wait for the bus; and, since schedules are frequently uncertain, many young children must wait from ten minutes to half an hour out in the open, regardless of weather. Transportation also tends to lengthen the time away from home, although the experience of two towns proves that much of this difficulty could be obviated by careful planning of the routes and adaptation of the length of school sessions to the age of the children as well as to the restrictions on transportation inherent in the geography of the town.

Massachusetts was the first state in the union to have a consolidated rural school; and it is hoped that the facts brought to light by the project now under way will provide information needed to enable the rural towns of the state to be the first to have ideal consolidated schools.

DEPARTMENT OF HORTICULTURAL MANUFACTURES

W. W. Chenoweth in Charge

The Extraction of Fruit Juices by Heat. (C. R. Fellers and F. P. Griffiths). Methods of extraction of fruit juices are being studied to determine which methods will give maximum yields of juice and jelly of good quality. Apples were first used. This work has been completed and is published as Technical Bulletin 15.

The work has been continued with small fruits including raspberries, blackberries, blueberries, currants, cranberries, and plums. The results indicate that two successive short extractions with approximately one-half as much water as fruit give the most jelly of optimum quality. The chemical composition of these fruits is also being studied.

In the course of the study a rapid centrifugal method for the determination of pectin has been worked out; also a method whereby the Bloom gelometer can be used to determine the jelly strength of fruit jellies. These are described in the above-mentioned bulletin.

Manufacture and Preservation of Cranberry Products. (C. R. Fellers and F. J. Griffiths). To date about 4000 cans of cranberry sauce have been packed in various types of tin and glass containers, stored at several different temperatures and periodically examined for discoloration, corrosion, perforation, flavor, color and jelly strength. The charcoal plate re-enameled tin can was the best container. The storage temperature for cranberry sauce was a very important factor in preventing deterioration and loss. The cooler the temperature, the better the sauce retained its original fine quality, color and flavor. At ordinary temperatures, cranberry sauce will keep in good condition for at least a year. Yield studies showed that one pound of cranberries will produce from 2 to 3 pounds of solid sauce depending upon whether the berries are whole, strained, or chopped. The discoloration of sauce was hastened by exposure to ferric iron and oxygen.

The pectin, acid and sugar content of cranberries picked at various times during the season has been determined in an attempt to correlate these factors with sauce manufacture. Although the total pectin content does not vary a great deal during maturity, there is a gradual lowering of its jellifying power, and fruit which has been stored for a few weeks gives reduced yields of sauce. Great individual variations among cranberry varieties were noted. "Floaters" and frozen cranberries, if promptly utilized were found suitable for sauce manufacture. If decayed fruit has been used to prepare sauce, the amount of decay can be determined approximately by means of a microscopic examination of the sauce.

These cranberry investigations have been carried on in close cooperation with the cranberry growers and packers, the American Cranberry Exchange, and the American and Continental Can Companies. The cans and sealing equipment were donated by the can manufacturers.

Utilization of Onions by Canning. (C. R. Fellers and F. J. Griffiths). This project has been in progress one year. The attempt has been made to utilize by canning, drying or pickling the cull and off-grade onions produced in this State in great quantities.

Large experimental packs of onions were canned in many types of containers, by various methods, and stored at different temperatures. Due to severe discoloration of the canned product, onions have not been canned successfully heretofore in quantity. In an attempt to eliminate this defect, cans with an inside enamel of zinc oxide were used with excellent results. By slightly altering the hydrogen ion concentration of the brine by the addition of a very small amount of an organic acid, the onion could be sterilized by boiling for from 45-60 minutes and still remain firm and whole within the can without injury to the flavor. It is hoped that markets for canned onions may be found.

Dried onions when firmly ground make an excellent "onion flavor" for use in cooking. It retains its color and flavor very well for at least a year and has proved very popular wherever used. A further study of this product is proposed.

Preliminary studies on pickling small onions have been uniformly successful except for the occasional development of yellow spots on the pickled onions. This defect requires study.

(See also the report of the Department of Plant and Animal Chemistry).

The Nitrogen Distribution of the Edible Portion of the Onion. (F. P. Griffiths). Work has been begun on this project, but definite results are not yet forthcoming.

Utilization of New England Fruits in Frozen Dairy Products. (C. R. Fellers and F. P. Griffiths in co-operation with the Department of Dairy Husbandry). An experimental pack of 190 one-gallon cans of frozen strawberries (10 varieties), raspberries (3 varieties), cherries (2 varieties), blueberries, and peaches (4 varieties) was made with a view to studying the use of these frozen fruits in the manufacture of frozen dairy products such as ice cream, sherbets, and ices. The effect of different amounts and kinds of sugar and of various methods of packing and handling, as well as variations in the technology of fruit ice cream manufacture, has been studied. It is also proposed to compare fresh, frozen and canned fruits.

DEPARTMENT OF LANDSCAPE GARDENING

F. A. Waugh in Charge

Lawns and Lawn Grasses and Lawn Management. (L. S. Dickinson). The necessity for correct fertilization of the lawn from its start is very clearly shown on the five-year-old lawn plots. Complete changes in grasses have been brought about by fertilizers, but during the change crab grass has been very prominent on both acid and alkaline plots. This is due to the fact that the grass that is being discouraged by a fertilizer is not replaced rapidly enough by another grass, the vacancies being taken by crab grass. On no plots where clover was plentiful was crab grass observed. Many varieties of weeds are found on the alkaline plots, and only a few on the acid.

The series of plots to determine the desirability of adding phosphoric acid and potash to nitrogenous fertilizers shows, after four years, that on rather heavy soil potash is not desirable. Bents are doing best on the plot receiving acid nitrogen plus phosphoric acid; fescues show best on the plots receiving acid nitrogen alone; and the blue grasses find weed competition too great in the plots receiving alkaline nitrogen plus phosphoric acid plus potash.

The putting green plots were used to make observations which might help in the accurate prediction of attacks of the brown patch disease. Seven attacks occurred, all of which started between the temperatures of 62° and 68°F., after a heavy saturation of the soil from rain or the grass by very heavy dew, combined with a sudden fall in temperature to within the above limits.

Fifty-six plots have been established in cooperation with the United States Golf Association, and nine plots have been established under trees to study shade-enduring grasses. Many new strains of bent have been added to the turf nursery and many data have been obtained for further study.

DEPARTMENT OF PLANT AND ANIMAL CHEMISTRY

J. B. Lindsey in Charge

The Efficiency of Copper Fungicides. (E. B. Holland). Additional work has been carried out in the laboratory relative to the preparation of low and high basic copper sulfates and the manufacturer advised as to the best method of procedure.

Field experiments were conducted with high basic sulfate in 1927, and with low and high basic sulfates in 1928. The materials were used both as a spray and as a dust mixed with a free flowing talc, and were compared with various commercial products or Bordeaux on apples, grapes, celery and potatoes. The results are promising as a whole, although the physical properties of the factory prepared basic sulfates are unsatisfactory and demand serious attention.

A number of papers have already been published on this project (see list of publications in this report) and it is hoped to publish details of the field work at an early date.

Nitrogen Intake of Havana Tobacco in Relation to Nitrogen Synthesis and Quality of Leaf. (E. B. Holland). The chemical work in connection with this project has consisted thus far of a study of the different forms of nitrogen in plants grown in the greenhouse in nutrient solutions, the object being to discover if possible the effect on growth and quality of leaf.

Samples from different parts of the plant grown in the field with the aid of different fertilizer mixtures will also be analyzed. The analytical work with the field samples will be confined largely to the nitrogenous compounds and to the ash, although the carbohydrates will also be given some attention.

The Department of Agronomy reports further on this project.

Nitrogen Fixation in the Presence of or as a Result of the Growth of Legumes versus Non-Legumes under Certain Defined Agronomic Conditions. (F. W. Morse). The crop grown on this field in 1927 was Golden Bantam sweet corn. It was used to measure the residual nitrogen and was planted on both legume and non-legume areas. In the spring of 1928, the legume plots were seeded with red and alsike clovers while the non-legume plots were seeded with timothy and red top grasses. The catch was good and the growth was fair; but owing to the extreme wetness of July and August, weeds, consisting of barnyard grasses and pig-weed, over-topped the clover and timothy when the crop was harvested in September.

The amounts of dry material and of nitrogen removed from the legume and non-legume areas since the beginning of the experiment are given in the following table. Before cutting the crop this season, observation indicated more growth on the non-legume than on the legume areas. This was confirmed by the yields of dry matter.

Although no nitrogen has been applied to Plots 7 and 9 since 1882 and probably an earlier date, the non-legume areas have not deteriorated in 5 years and in 1927 and 1928 were even superior in weights of dry matter and nitrogen removed in the crops..

Dry Matter and Nitrogen Removed from Plots Treated with Nitrogen (Kilograms per Acre.)

Legumes alternating with corn.

		1924	1925	1926	1927	1928
Plot		*Clover*	*Corn*	*Soy beans*	*Corn*	*Clover*
7	Dry matter	1552.	1476.	1504.	1084.	1214.
9	Dry matter	1868.	1766.	1596.	1164.	1334.
7	Nitrogen	43.2	24.1	35.1	17.9	
9	Nitrogen	49.9	29.8	39.9	18.4	

Non-legumes alternating with corn.

		1924	1925	1926	1927	1928
Plot		*Grass*	*Corn*	*Millet*	*Corn*	*Grass*
7	Dry matter	408.	922.	2206.	1104.	1444.
9	Dry matter	496.	1010.	2126.	1294.	1478.
7	Nitrogen	3.4	12.9	16.5	18.7	
9	Nitrogen	4.5	13.1	14.0	21.7	

A report of another phase of this project is given by the Department of Bacteriology and Physiology.

Chemical Changes in the Cranberry during Ripening and after Harvesting. (F. W. Morse). Cranberry ripening has been studied for two seasons with the fruit of 1926 and 1927. Two varieties, Early Black and Late Howes were compared. Pickings were made at weekly intervals from the last week in August when the early fruit was beginning to redden until the first week in October when the late berries were well colored. Water, sugar and acidity were compared as the growth of the fruit progressed.

The development of the berries resulted in a small percentage decrease in water and doubling the sugar content while the acidity was practically constant throughout the ripening process. The early variety was well ripened when the last picking was made by the last week in September; but the late variety was not at its maximum content of sugar until two weeks later. The late variety is usually harvested before it is fully ripe in order to escape frost.

The mineral matter contained in cranberries was comprehensively studied and an article has been prepared for publication. Since cranberries contain generally less than .2 per cent of ash their mineral constituents are not striking. As sources of iodine and manganese, they were found to be relatively richer in these elements than some of our common fruits.

A Study of the Availability of Soil Potash with the Object of Developing a System of Diagnosis for the Soils of the State. (F. W. Morse). This project has remained quiescent during the past year, except that some literature has been reviewed to determine the next steps. The publication of soil surveys of the State is essential for the satisfactory pursuit of the project. This past year a survey of Worcester County has been issued.

Utilization of Onions by Canning. (C. P. Jones). Chemical analysis of the blanched edible portion of the onion has shown the following: On the green basis (84 to 90 per cent water), the percentage of total sugar varied from approximately 5 to 11 per cent. The protein content ranged from approximately 2 to 2.5 per cent. Fat and crude fiber were found in small amounts. The substantial differences in amounts of chemical substances found are due to the fact that two kinds of onions were examined, —seed and set onions. The differences were found not only in moisture, sugar and protein, but also in ash, alkalinity of ash and total sulfur. Both the calcium and the magnesium contents were equal in the two kinds of onion.

The relation of calcium to magnesium was found to stand in a ratio of one to one. A field study of the effect of the ratio of calcium to magnesium upon the growth of the onion would seem justified.

In the process of canning onions, discoloration or darkening of the tissues has been observed. In order to make the canned product more attractive and consequently salable, the causes and preventives must be understood and controlled.

Although the principal oily substance contained in the onion has been stated to be a disulfide of allyl, work thus far has indicated that mustard oil is present in addition to the sulfides of allyl, in spite of the fact that the literature, with one exception, fails to recognize mustard oil as a constituent of the onion.

Anthocyan pigments of fruits have been found to react with metal of containers, producing various color reactions with consequent discoloration of the canned product.

The onion contains a flavonal pigment. Work upon this pigment as well as upon the essential oils and their effect upon metals is being continued.

Lime Penetration Resulting from Surface Application to Pasture Land. (P. R. Nelson). This project has been completed and prepared for publication. It represented a study of a Gloucester sandy loam in permanent pasture, different plots on which had received different fertilizer treatment. It was found that the greater part of the calcium had remained at the point of application and exerted its influence there. There was a slight trend towards a gradual penetration to a depth of nine inches. Of the three materials applied in addition to the ground limestone,—muriate of potash, acid phosphate and gypsum—the only one appearing to have the slightest neutralizing effect upon the soil was gypsum, and its effect was quite distinct from that caused by the lime alone.

Record of the Station Herd. (J. B. Lindsey and J. G. Archibald). The station keeps 12 to 16 cows for its experimental work, in addition to young stock. The records for 1927 show that of the 16 cows in the herd 9 only represented the herd for the entire year. These 9—of which 7 were grade Holsteins, one a high grade Jersey, one a purebred Jersey—averaged 10,294 lbs. of milk for the year testing 12.67% solids, 4% fat, with a food cost of $176.09 per cow or 3.76 cents per quart. The food cost was based on hay at $20, green feed at $8 a ton and grain at market price. The complete records for 1928 are not yet available.

Milk Substitutes in the Growing of Young Calves. (J. B. Lindsey and J. G. Archibald). For several years the experiment station at Amherst has carried on extensive feeding trials on the value of different feeds for raising young calves. Experiments with calf meals and preliminary trials with skim milk powder were reported in Bulletin No. 223. The powdered skim milk offered the most fruitful field for further study and during the past three years, a large number of calves, mostly high-grade Holsteins, have been raised on it.

There are two distinct types of skim milk powder on the market, one manufactured by the so-called "roller" process, the other by the "spray" process. Both kinds have been fed at the rate of 14 ounces of the powder to a gallon of water. The powder may, however, be fed as dilute as one pound to five quarts of water. The "roller" process powder is more economical at present prices and mixes with water more rapidly.

In the earlier experiments the maximum amount of skim milk powder (31½ ounces of the dry powder to 9 quarts of liquid) was fed daily until the calves were four months old.

During the past year calves have been reared on much smaller quantities of the powder, the object being to cut the cost.

The procedure has been similar to that followed in our earlier work except that when the calves were two months of age their daily allowance of skim milk powder was cut to 21 ounces (6 quarts of liquid) and at three months was again cut to 10½ ounces (3 quarts of liquid), and a special effort was made all through the experiment to induce the calves to eat heartily of the dry grain mixture and rowen.

Under present conditions dried skim milk fed as above suggested offers the best substitute for liquid skim milk in the rearing of young calves. Calf meals are fairly satisfactory but are apt to cause digestive disturbances and do not promote as rapid growth.

The value of buttermilk powder for calves has lately been investigated. It has produced gains at almost the same rate as did the skim milk powder and rather more economically because of lower market price. Calves do not consume it as readily at first as they do skim milk powder, and it has a decided laxative effect in some cases.

This work with skim milk substitutes was also reported in the August, 1928, issue of the Eastern States Co-operator entitled "Skim Milk the Standard". The article was based on a talk given by Mr. Archibald during the 1928 Farm and Home Week at M. A. C. Mimeographed copy of detailed method of feeding furnished on request.

The Value of Calcium Phosphate in the Promotion of Growth and Milk Production. (J. B. Lindsey and J. G. Archibald). This experiment has been in progress for a number of years. The entire herd of cows was fed a basic ration low in mineral matter, and to one-half of the herd the mineral supplement consisted of especially prepared bone meal. The results in the main were negative. The experiment was reported in the Proceedings of the American Society for Animal Production. The supplement during the last two years has been a mixture of 4 parts of dicalcium phosphate and 1 part calcium carbonate. The accumulated data from this experiment are now being studied and a final publication reviewing our work with bone meal, and giving in some detail the results from the latter experiment will be ready for the press within a few months. The indications are that the dicalcium phosphate and calcium carbonate were of some benefit but this is not at all marked.

The Mineral Constituents of Forage Crops. (J. B. Lindsey and J. G. Archibald). Because of the scarcity of data available showing the mineral constituents of the ordinary roughage grown in Massachusetts, numerous determinations of calcium and phosphorus have been made on both the roughage and grain fed in connection with our experiment on the need of minerals by dairy animals. In addition, sixty-eight samples of hay and silage were collected in different sections of the State, with the aid of the county agents. The entire analytical work will be published as a part of the publication on the mineral needs of dairy cattle.

In general, it can be said that while individual samples varied widely the data showed no pronounced deficit of mineral constituents.

Mineral Requirements for the Growth of Dairy Heifers. (J. B. Lindsey and J. G. Archibald). Comparatively little information being available in the literature, an experiment was undertaken some two years since to determine as nearly as possible the mineral requirements of dairy heifers up to two or more years of age. Eight heifers are at present under test, the intake and outgo of calcium and phosphorus in each case being accurately determined. One group is receiving a diet high in calcium and another group a ration rather low in this ingredient. It is too early yet to draw any conclusions from the data already secured.

DEPARTMENT OF POMOLOGY

F. C. Sears in Charge

The Interrelation of Stock and Scion in Apples. (J. K. Shaw and J. S. Bailey). The usual observations of the growth, bloom, and yield have been continued. Information to date has been tabulated and a bulletin reporting results is in process of preparation. The general results of this investigation seem to indicate a rather less influence of stock than had been expected. These trees were grafted at the surface of the ground. Possibly if the union had been higher up results would have been different. The results suggest that stock influence is more likely to dwarf trees than to invigorate them.

Investigation of the clonal stocks from East Malling, England were continued. Mound layering gave rather poor results, and attempts to propagate several of the stocks from cuttings planted in the field resulted in complete failure. When cuttings were grafted on nurse roots from ordinary apple seedlings, good success was achieved and practically all the trees rooted from the scion and are now on their own roots. A considerable number of these stocks were dug and root cuttings made and planted in the spring of 1928. A good percentage of these started into growth and bid fair to produce good stocks although the first season's growth is rather small.

About 300 McIntosh and Wealthy trees on East Malling stocks were planted in the orchard in the spring of 1928.

Tree Character of Fruit Varieties. (J. K. Shaw and A. P. French). Further observations have been made on the varietal characteristics of apple and other nursery fruit trees. These observations are being brought together in a bulletin designed to replace and extend Bulletin 208, "Leaf Characters of Apple Varieties." Plans are being made to extend and intensify work under this project by means of a nursery in which will be grown all apple varieties generally propagated by nurserymen. It is hoped that in time this work may be extended to fruits other than apple. The results of this work continue to be applied in a practical fashion in nurseries, and it is hoped will result in a substantial decrease in the number of mixed varieties sold by nurserymen.

The Genetic Composition of Peaches. (J. K. Shaw and J. S. Bailey). About 1200 selfed and cross-fertilized seedlings resulting from work in previous years were planted out in the orchard in the spring of 1928. The parent trees failed to bloom in the spring of 1927 because of winter-killing of the buds. In 1928 some further crossing was done, but the results were rather disappointing owing to poor set of fruit.

A freezing apparatus for the purpose of studying the bud hardiness of seedlings and parent varieties was constructed in 1927 and further developed in 1928 by attaching to the refrigerating plant in the cold storage building. This will soon be in operation and promises to furnish excellent means of studying bud hardiness. In this way much more rapid progress can be made than by waiting for test winters.

Head Formation in Apple Trees. (J. K. Shaw). This project has been completed and the results published. (Bulletin 238). The orchard in which these studies were made has been utilized for a fertilizer experiment. The trees now receive a moderate annual pruning, excepting those which have never been pruned. This treatment is being continued to see what the effect of no pruning on young trees may be.

Testing Methods of Pruning. (J. K. Shaw). This project involves a comparison of heavy, light and no pruning in a young bearing orchard. Several varieties are included in this test, but the results must be based on Wealthy for the other varieties appear in relatively small numbers. The unpruned trees are developing very thick tops, especially on some varieties, but thus far no distinct differences in quality and quantity of fruit appear.

Effect of Pruning on Bearing Apple Trees. (F. C. Sears and J. K. Shaw). The fertilizer experiment started in this orchard in 1889 has been discontinued, and the plots now receive equal amounts of nitrate of soda. A comparison of heavy, light and no pruning is now being made on these trees. This work was begun in the spring of 1927. It supplements the pruning test in the preceding project, using trees nearly forty years old instead of young bearing trees. The first two years of the experiment have shown no marked effect on quality and quantity of apples produced.

Comparison of Cultivation and Sod in a Bearing Orchard. (J. K. Shaw). This project had been continued on a fixed program since 1921. In the spring of 1927 it seemed wise to redirect the work. One of the plots which had previously been in cultivation without fertilization has received for the past two years the same amount of nitrogen that the sod plots have been receiving—300 pounds of nitrate of soda per acre. This seems to have favored production of the Baldwin very distinctly, and there appears a less distinct improvement in the production of the McIntosh.

One of the sod plots which had received nitrogen has been continued on the same program. A second plot has received an additional application of nitrate of soda, 200 pounds per acre, at about the time terminal growth stopped. This seems to have favored production with the Baldwin and shows a less distinct improvement with the McIntosh. The third sod plot has received 200 pounds per acre of sulfate of potash in early spring. There is no indication that this has improved production with the Baldwin, but it may have slightly favored production with the McIntosh.

The fertilizer test now being carried on in the orchard previously devoted to a study of Head Formation may be considered a part of this project. The orchard is entirely in cultivation and from planting in 1916 to 1925 received no fertilizer. The trees showed some indications of nitrogen definciency. The orchard was divided into seven plots; four of these are now receiving nitrogen equivalent to 300 pounds per acre of nitrate of soda, the other three plots continue to receive no fertilizer. The fertilized plots show improved color of foliage and should show improved yields. Of course no conclusions can be drawn for several years.

Comparison of Clover Sod and Grass in Sod Mulch Orchard. (J. K. Shaw). This project has been continued as in the past and the usual observations made. The plots receiving complete fertilizer have shown rather better production than those receiving phosphorus, potash and lime.

The purpose of the latter treatment was to bring in a white clover sod. No white clover appeared previous to 1927, but during the past two years areas of white clover have been developing. Determination of soil nitrates indicated considerably more under the clover than elsewhere. It is now planned to continue this project to see if the clover will increase and if it is effective in promoting growth and fruitfulness of the trees.

Test of Different Amounts of Nitrate of Soda. (J. K. Shaw). This project involves a number of Baldwin trees now thirty years old, growing in sod. Since 1922 they have received 5, 10 or 15 pounds of nitrate of soda each year in addition to adequate amounts of phosphorus and potash. The general results seem to be that production increases with the amount of nitrate applied. No injurious effects on the trees or on the color of the fruit have been observed. In the spring of 1928 the amount of nitrate was increased to 10, 17½ and 25 pounds of nitrate of soda per tree.

Comparison of Cultivation and Heavy Mulching for Apples and Pears. (J. K. Shaw). This experiment has been continued as started in 1922. The marked difference in foliage color of the trees on the two treatments was less distinct in 1928 than in previous years. Most of the mulched trees continued to yield heavier crops and no injurious effects have been observed. This is remarkable. The amount of nitrates in the soil under the mulch is far in excess of that usually found in cultivated orchards receiving annual applications of nitrate of soda; shoot growth continued no later in the summer; and the apples are similar in every respect on the two plots. The trees on the unfertilized cultivated plots continue to grow rather slowly and are evidently slowly exhausting the fertility of the soil.

The Effects of Fertilizer Limitation on Fruit Plants. (J. K. Shaw). This project deals with apple and peach trees and grape vines planted in 1922 on an old fertilizer test field which, for nearly forty years, had received fixed fertilizer applications involving nitrogen, phosphoric acid, and potash alone and in combination. The remarkable result of this experiment is that the only fertilizer effect seen is on the plots which have received potash and which have been limed. The unlimed portions of the potash plots show no better growth than the plots which have never received any fertilizer. The same is true of all fertilized plots not receiving potash. In order to further investigate this condition, a new project has been formulated and pursued during the past season.

Role of Potash and Lime in Fruit Tree Nutrition. (J. K. Shaw). In order to throw light on the puzzling questions that arose in the preceding project, experiments were carried out in Wagner pots. Soil from two of the plots was placed in pots in the summer of 1927 and seedling peach trees planted as indicators. The behavior of the trees in the pots was similar to the behavior of the trees in the field plots. Also the Wagner pot proved to be satisfactory as a container.

During the summer of 1928, 115 pots were filled with soil from a number of these field plots, and seedling peach trees planted. Some of the soils were placed in the pots without treatment, and others received various fertilizers and in some cases certain amounts of lime. Each treatment was replicated five times. The general question was whether the results shown in the field plots were really due to the soil treatment; and the answer was, in general, affirmative. Additions of lime to the soils which had received potash resulted in increased growth and increased amounts of nitrates in the soil. Determinations of soil nitrates and of the pH value of the soil in the pots were made during the season. It is unsafe to conclude that fruit trees would respond to potash on all the soils in the State; but these results suggest the possibility that there may be some soils that would respond to potash and lime.

Effect of Potash and Lime on Apple Trees. (J. K. Shaw). The original project on the orchard here considered was a test of cover crops. This test continued for six years, giving very doubtful indication of any influence on the trees from the cover crops used. It became evident that it would be many years before any marked differences could be expected to appear. Therefore, in the spring of 1927, the project was redirected into what is practically a new project. The same plot arrangement was retained, but the whole orchard has been seeded to grass, and a fertilizer treatment adopted using nitrate alone, potash alone, nitrogen and potash, phosphorus and potash, and complete fertilizer, each treatment receiving lime in addition on two plots and not receiving lime on another two plots. It is too soon to expect any results from this new project, but it is hoped that it may help to answer the question of the value of potash and phosphorus which is in the minds of growers at the present time.

Study of Varieties of Tree Fruits. (J. K. Shaw and O. C. Roberts). The College and Station grow a large number of varieties of tree fruits. Records of bloom and production are being taken on practically all varieties including those not used for Experiment Station purposes. These records have been accumulating for several years and will be available for studies of varietal habits, bloom and yield. It is expected that in some future time as these records accumulate they may be available for study of the relation of climatic conditions to bloom and yield.

The Cultivation of the High Bush Cranberry. (J. K. Shaw). This project involves the study of a number of plants of high bush cranberry received from the United States Department of Agriculture. These plants are still growing and are producing annual crops. It seems doubtful if this effort will find any great application in practice, and probably this project will be discontinued in the near future.

Fruit Bud Formation in the Strawberry. (R. A. Van Meter). This project was started in the spring of 1928 to study the effect of the supply of soil nitrates on fruit bud formation and fruit production. It involves nine fertilizer treatments, each replicated five times, on plots of thirty plants each. Runner plants were spaced equally or removed to eliminate crowding.

The field was fertilized with superphosphate at the rate of 600 pounds per acre and muriate of potash at the rate of 150 pounds per acre, broadcasted and worked into the soil before planting. The differential treatment of the plots consisted in the application of nitrate of soda at the rate of one pound per plot or 322 pounds per acre on the following dates:

1—No nitrate of soda
2—May 11 (immediately after planting)
3—June 13 (when plants were well established)
4—July 2
5—August 6
6—August 20
7—September 5
8—September 15
9—October 4

No apparent differences in plant growth appeared the first season, and observations on the number of fruit buds formed cannot be readily made until next spring, when a careful study of fruiting behavior will be made.

A new plantation will be started in the spring of 1929, probably with some revision of the schedule of applications, omitting the earlier applications and adding two or three plots treated with certain forms of organic nitrogen-carrying fertilizers.

Work not on Project Basis

Considerable experimental work is being carried on by members of the department not on the Station staff. The principal lines of work are briefly reported below.

Cross-pollination and Sterility Studies with Certain Apple Varieties. (F. C. Sears, O. C. Roberts and others.) This work has been in progress since 1925. The value of Delicious, Gravenstein, Rhode Island Greening, Wagener, Cortland and other Varieties for pollinating Baldwin, McIntosh and Wealthy has been studied; also the value in inter-crossing of the latter three varieties and their ability to set fruit with their own pollen.

Baldwin and Wealthy have proved more or less self fruitful and McIntosh practically self unfruitful. Rather distinct differences in value of the several varieties in cross pollination have been obtained.

It is planned to continue the work and to publish the results at some future time.

The Effect of Freezing Temperatures on Apples. (O. C. Roberts). Apples are frequently chilled before harvest due to early and unexpected periods of cold weather, and the effect on the keeping quality of the fruit is not well understood. A series of tests for the purpose of gathering observations along this line was started in 1926. Apples are allowed to freeze on the trees and then harvested and stored under varying conditions. The results of the past two seasons seem to indicate that certain varieties, at least, may be successfully stored even though they may have been subjected to freezing temperatures.

Studies of the Arsenical Residues on Apples. (O. C. Roberts cooperating with the Department of Entomology). This represents an effort to meet the requirements of Health and Food inspection authorities who are trying to make sure that no apples carrying an excessive amount of arsenic reach consumers. Amounts of arsenic closely approaching or exceeding the tolerance of .01 grain per pound have been found only with early varieties and where trees were sprayed later than is usual in practice. On the whole the investigations indicate that this problem is not likely to be troublesome in Massachusetts orchards where a proper spraying practice is carried out.

Light Pruning of Young Grapevines. (B. D. Drain). This work has been carried on for one year only. The vines were pruned less than is usual, leaving about twice the usual number of buds. The blossom clusters were thinned in June. This method, as compared with the usual method, gave 23 per cent increase in production with no decrease in the quality of the crop.

DEPARTMENT OF POULTRY HUSBANDRY

J. C. Graham in Charge

Broodiness in Poultry. (F. A. Hays). The relation of broody behavior to other characters concerned in high egg production has been further studied. Linkage relations have been discovered between winter intensity and the presence of broodiness. Total days spent in broodiness has been shown to exhibit an important negative net correlation to annual egg yield.

Some evidence is available to indicate that non-broody birds are less vigorous than broody individuals. The total percentage of broodiness in the flocks has been very significantly reduced during the period and now stands at 19 per cent.

During the mating year of 1928 the broody character has been studied from three major aspects:

1. Inherited factors concerned in degree of broodiness.
2. Influence of management upon broody behavior.
3. Physiological phases have been studied to ascertain if the stimulus to broody behavior lies in the ovary or in the testes.

Breeding Poultry for Egg Production. (F. A. Hays). The mean annual egg production for all birds in this experiment for the year ending in 1927 was 205. Records are not yet fully complete for the flock whose year ends in 1928. During the past year particular attention has been given to a study of the breeding behavior of intensity measured by winter clutch size. Winter clutch size has been shown to be inherited. Winter pause is being studied with special reference to its relation to other fecundity traits. Persistency has been given special attention in its linkage relation to early sexual maturity and also in its relation to calendar date. A very satisfactory degree of uniformity in age at first egg and in annual persistency has been attained. Special efforts are being directed toward the establishment of uniform, high fecundity and maximum livability.

Three papers have been published under this project,—Scientific Contributions Nos. 53, 56 and 63.

Statistical Study of Heredity in Rhode Island Red Breed of Poultry. (F. A. Hays). During the period covered by this report, three bulletins have been published under this project—Technical Bulletins 11 and 12, and Bulletin 242.

Data are now being assembled for a bulletin on normal growth in Rhode Island Reds.

Particular attention is given under this project to the interpretation of data now on hand and the application of the findings to further progress.

A Genetic Study of Rhode Island Red Color. (F. A. Hays). The past two years have been devoted to the application of the theory regarding the inheritance of Rhode Island Red color proposed in 1926 to the strain bred intensively for high fecundity since 1913. Progeny closely approaching modern "Standard" color have appeared. These results indicate that no genes for "Standard" color pattern have been lost. The present problem lies in the establishment of a heavy laying "Standard" color strain. Present breeding stock consists of parent stock and 51 pullets and several cockerels to be used in future study. Complete color descriptions of all birds are on file.

Determination of Genetic Laws Governing Results in Inbreeding Poultry. (F. A. Hays). The ultimate object of this project is to measure the effects of different degrees of inbreeding upon characters concerned in egg production. Seven inbred strains were started in 1923. By 1928 only two of these strains had survived, the others disappearing because of low fertility and high mortality. The two remaining strains were crossed in 1928 and also bred as such. There have been no important advantages observed to come from inbreeding and undesirable results are common. Results will be published in the near future.

Hereditary and Environmental Factors Affecting Variability in Egg Production. (F. A. Hays). This experiment was begun in the spring of 1928. Three pen matings were made using birds that were distinctive regarding variability in egg production. The first pen consisted of ten yearling hens mated to a yearling male. This pen was made up of families of sisters that were especially uniform in the five important characters affecting annual production mated to a male from a similar family. The second pen contained ten yearling hens selected for uniform egg production only and they were mated to a male of their own age from a similar family. The third pen of ten yearlings was selected for high annual egg production alone and they were mated to a male from high producing ancestry.

The parent stock, 165 pullets and several cockerels are now available for study.

Factors Governing Egg Weight and Shell Character in Domestic Fowl. (F. A. Hays). Preliminary studies on egg weight began in the spring of 1925, when all eggs laid by the breeding females between February 22 and March 3 were weighed and described. The same procedure has been practiced each season to date. In the fall of 1927 each egg was weighed as taken from the trapnests for the entire flock of 750 pullets housed. The records began with the first egg of each individual and continued until January first.

The present project was formulated in the fall of 1927 and became active in 1928. Three pens of ten pullets each were selected on the egg weight basis and mated to three full brothers in 1928. The first pen laid eggs averaging 52 grams in December, the second pen laid eggs averaging 57 grams in December and the eggs of the third pen averaged 59 grams in December. All eggs incubated were weighed and described. A total of 120 pullets from these pens have been retained for study and cockerels are available for further breeding operations.

Relation of Intensity or Rate of Laying to Feather Pigmentation. (F. A. Hays). This project began in the fall of 1927 when 50 extremely light-colored and 50 very dark-colored pullets were selected to study possible relations between shade of color in Rhode Island Reds and intensity of laying. No very significant relations have appeared in these groups to date.

For the matings of 1928 two pens of ten pullets each were used. These pens were made up of pullets from the above two groups, the dark pen mated to an extremely dark male, the light pen to an extremely light-colored male. From these matings 59 pullets and several cockerels are available for breeding tests.

Studies of egg weight records indicate that egg weight depends upon two genes in its inheritance. Results of these studies will appear as a technical paper in the Journal of Agricultural Research.

DEPARTMENT OF VEGETABLE GARDENING

(Market Garden Field Station, Waltham)

F. A. Waugh in Charge

Conditions Affecting the Production and Vegetative Propagation of Washington Asparagus. (V. A. Tiedjens). Roots of various ages have been used for establishing high producing clonal varieties of staminate and pistillate asparagus varieties. Considerable difficulty has been experienced in propagating plants whose buds have reached their maximum size. Crowns having small or immature buds may be propagated with much less difficulty. One-year roots may be divided into one to eight pieces, depending on their size, and produce suitable roots. Attempts have been made to propagate parts of the plants other than the crowns but with no success. On old plants only immature crown tissue can be used. The practice of propagating old roots is attended with uncertain success, because of the age of some of the tissue. Clones from old roots vary in their ability to recover from the injury to the buds caused by the separation of the crowns into smaller sections. All the cuttings will grow from some roots, while none will grow on others. Some crowns on old plants producing small buds will readily divide into many pieces without the use of a knife, while on others the buds are so closely knit together that it is impossible to divide them into two pieces without cutting through the buds. The former are more readily propagated because of less interference with the buds when the cuttings are made.

It is important that the cutting be done parallel to the plane of the buds, if clusters of buds must be divided. New buds originate at the base of growing stalks. Well grown, one-year-old crowns have buds ranging in size from very small to the largest. The cuttings from the small buds do not produce as large roots as the cuttings with the large buds, and the roots in a clone vary in size. The variation in size, however, is soon overcome. This is probably a growth relationship,—the small buds being a surplus in the cycle of development of the crown.

Because of the ease with which clones may be developed from one-year-old roots, an attempt has been made to grow the seedlings so that the genetic potentialities may be shown at the end of the first season's growth. The practice is to plant the seed rather thickly in drills, from the first to the middle of August, and mulch the small seedlings heavily to protect them from winterkilling. The following spring they are transplanted equal distances apart and used for propagating material a year later. The distribution of buds on the crown,—their size and size of the crown,—make it possible to select types which are best suited for propagation purposes.

Progenies from individual plant selections are grown by the above method and decided differences in vigor transmitting qualities have been found. It emphasizes the relation of genetics to the vigor of the plants, a fact that has an important bearing on the efficacy and commercial value of the vegetative propagation of asparagus.

A propagating frame has been devised, comprising ten hotbed sash with a hot water heater to warm the soil by means of pipes buried twelve inches below the surface. When cuttings are made in the spring, the crown tissue will decay if the soil is not warm enough for growth. In cold weather the mortality is very high so that cuttings must be started in the propagating frame. They are either divided again or transplanted in the field after growth has started. Conditions suitable for propagation of most cuttings are necessary for propagating asparagus cuttings. If the cuttings are slightly dried before planting, there will be less danger from decay attacking the soft tissue in the crowns.

Roots on old plants serve merely as reserve food for the establishment of the cutting, and new roots must be formed before the cutting can draw on the soil moisture. Old roots do not send out secondary roots. New roots (one year old) send out secondary roots, and if not injured will continue to serve as feeder as well as storage roots. This is in a large measure responsible for the greater ease with which one-year roots may be propagated.

On one-year crowns, roots that have been broken off will send out secondary roots but will not grow in length. Occasionally a secondary root near the broken end of the storage root will develop sufficiently to function as a storage root.

The Genetics of Greenhouse Cucumbers. (V. A. Tiedjens). A number of characters have been isolated in cucumbers. Green fruit color is dominant over white; orange or bronze fruit color (sun color) linked with the black spines, dominant over white and green fruit color, develops only in the presence of light. Black spines are dominant over white spines. Parthenocarpy is epistatic to development by fertilization. The location of pistillate flowers on the main stem is epistatic to the allelomorph inhibiting the production of pistillate flowers. The abundant production of laterals is dominant to the absence of laterals.

Such characters as size and shape of fruit, and number of flowers show partial dominance or follow the laws of quantitative inheritance and are materially influenced by environmental conditions.

The following pure lines have been established:

1. Types varying from abundant to very light sets of fruit and staminate flowers.
2. A selection having pistillate flowers on the central stem.
3. A selection having no pistillate flowers on the central stem.
4. Selections varying for color, size and shape of fruit.
5. Selections that have spines and warts in various degrees of intensity.

A number of crosses involving certain relations have been made but insufficient data are available to draw conclusions.

A commercial variety that will combine desirable market qualities and develop parthenocarpically is under observation. The extreme heterozygous condition of cucumber varieties makes it necessary that a commercial variety should have its characters represented by homozygous factors in order that a stable, uniform commercial variety will give expected results under varying growing conditions.

Cold Resistance in Sweet Corn in its Relation to Quality, Size and Earliness. (V. A. Tiedjens). As a result of selecting from 600 ears of sweet corn on the basis of their ability to germinate at low temperatures for two years, one selection from the Whipples' Yellow variety has been saved for further testing. A cross between this selection and a very early Canadian sweet corn was made. The first generation seed is being grown in the greenhouse during the winter months with the use of electric light. This hybrid material will be germinated at a low temperature and selections will be made combining low temperature effects with other desirable characters, toward the production of a large, yellow, early variety that will grow under unfavorable weather conditions.

Factors Influencing the Heading of Greenhouse Lettuce. (V. A. Tiedjens). Because of the decline of the greenhouse head lettuce industry, a study of factors affecting the heading of lettuce has been discontinued.

The breeding of a mildew resisting, hard heading type for winter growing conditions has resulted in a selection that promises to take the place of the Belmont and May King varieties. The selection was made from a cross between Belmont, a firm heading type but susceptible to mildew, and May King, a large loose-heading, mildew-resistant type. The variety has been named Bel-May. It is not as resistant to mildew as May King, but a firmer heading type for winter conditions. Apparently, resistance to mildew is correlated with the more open type of growth shown by the May King variety.

The new variety is being grown by several growers for a commercial test and is showing considerable promise.

The Improvement of Beets Through Selection of Roots and Seed Production. (V. A. Tiedjens). Cooperation with Wyman Brothers of Arlington, Mass., has made available a fine selection of beets.

The Improvement of Carrots Through Selection of Roots and Seed Production. (V. A. Tiedjens). A fine selection of Hutchinson Carrot has been developed, and last year over 200 pounds of the seed was distributed to growers. This is now in the hands of the Seed Committee of the Boston Market Gardeners Association who are merchandizing the seed.

DEPARTMENT OF VETERINARY SCIENCE

J. B. Lentz in Charge

The Standardization of Avian Diphtheria, Roup or Bird Pox Virus and Vaccines with Special Reference to Improving the Treatment of the Disease. (N. J. Pyle.) Since the publication of Technical Bulletin No. 14 in June, 1928, progress has been made in the study of the duration of the immunity produced by the cutaneous vaccine and in the results of its administration to birds as it may affect egg production, body weight, and temperature. It is planned to make further studies on the standardization of the vaccine.

Laboratory Service—Pathology. (G. L. Dunlap.) From December 1, 1926 to June 15, 1927, 2,422 specimens were examined. These included 1,272 chicks, 95 adult chickens, 3 ducks, and 1,052 miscellaneous. From June 15, 1927 to June 30, 1928 this service was suspended, except for examinations of urgent material, which included 578 miscellaneous specimens. On July 1, 1927 it was resumed, with a fee of $2.00 for each examination. Since July 1, 68 examinations have been made with a total of 160 specimens. These include 106 chickens, 1 turkey, 6 foxes, 5 pigeons, 1 rabbit, 2 feed samples, and 39 miscellaneous specimens.

Poultry Disease Elimination Law. (W. R. Hinshaw and E. F. Sanders). The progress made in the control of Salmonella pullorum infection (Bacillary White Diarrhea) is summarized in Control Series Bulletins 39 and 43, which record the results of agglutination testing for the 1926-27 and 1927-28 seasons.

During the 1926-27 season, 127,327 tests were made in 249 flocks and 114 of these flocks, comprising 40,269 birds, were reported negative to the agglutination test. During the 1927-28 season, 232,091 tests were made on 321 flocks and 138 flocks, comprising 80,829 birds, were reported negative.

Based on the 1925 poultry population of Massachusetts, it is estimated that 9.39 per cent of the chickens in the State were tested in 1927-28 as compared with 6.27 per cent in 1926-27. Using the same comparison, 3.98 per cent of the chickens of the State were in non-reacting flocks in 1927-28, as compared with 1.98 per cent in 1926-27.

Following the 1927-28 testing season a questionnaire was sent to the 321 flock owners for whom testing had been done. Some of the information obtained from the 239 replies is presented.

Effect of bleeding on egg production: one person reported egg production increased by bleeding, 166 reported "no effect", and 72 reported losses from 0 to 50 per cent, due either to bleeding or to handling of the birds or due to both.

Mortality traceable to blood collecting: thirteen persons reported a total of 50 birds lost from hemorrhage following the withdrawal of blood. Four persons reported the death of 12 birds due to causes other than hemorrhage but indirectly traceable either to bleeding or to handling of the birds. A total of 62 birds or .026 per cent of all birds bled during the 1927-28 season were reported having died as a result of blood collection.

Kinds of disinfectants used: twenty-nine brands of disinfectants were reported as being used for spraying the hen houses after the removal of reactors. Seven of these are included on the U. S. Department of Agriculture B. A. I. approved list, (B. A. I. Circular Letter 1508) and ninety-six poultrymen were using these approved disinfectants.

SPECIAL TOBACCO INVESTIGATIONS

Conducted by the Bureau of Plant Industry, United States Department of Agriculture, in cooperation with the Massachusetts Agricultural Experiment Station.

H. F. Murwin, U. S. D. A., in Charge

Brown Root-Rot. (H. F. Murwin). Plot work is being conducted at Whately to study comparative effects of preceding crops on the growth of tobacco both in healthy and in infested soil with two acidities in each case. It has been demonstrated in these experiments that certain crops may not only inhibit recovery from brown root-rot in infested soil but may actually bring about this condition in healthy soil. The crops used were alfalfa, corn, clover, tobacco, timothy, soy beans, potatoes, oats, field peas and two types of fallow. These crops were grown two successive years and followed by tobacco in each case. Tobacco made a good growth following tobacco, fallow and oats on both healthy and infested soil. The detrimental effect of corn, alfalfa, clover, timothy and soy beans on the tobacco crop was quite marked in both cases and the effect of potatoes and field peas was intermediate. To date no beneficial effect on tobacco has followed any crop except oats, and even here the yield was no greater than in the case of tobacco following tobacco or fallow. Brown root-rot has never resulted from continuous culture of tobacco on healthy soil in these experiments, and the yield of tobacco has invariably improved from one year to the next with continuous culture on infested soil. The above results were obtained on rather acid soil, and no data on crop effects have been obtained from the less acid plots to date.

It is quite evident from these tests, together with observations throughout the Valley, that brown root-rot is, in the great majority of cases, the result of some crop effect. This would indicate that cellulose decomposition might play a part in bringing about such a condition on tobacco roots. However, cellulose decomposition, as such, does not appear to be responsible for the occurrence of brown root-rot. Practically pure cellulose was applied to the extent of one per cent of the weight of the soil in combination with ample nitrate nitrogen, and this amount of cellulose was also applied on unfertilized field plots, but no symptoms of brown root-rot were present on the roots at harvest. The tests have also demonstrated that ordinary applications of fertilizers have little or no effect on brown root-rot. Twice the ordinary application of a commercial tobacco fertilizer, or heavy applications of nitrate nitrogen have failed to improve the yield of tobacco on infested soil.

In summarizing, no crop under investigation, with the exception of oats, has proven beneficial to a following crop of tobacco either on infested or healthy soil. The data on oats as a preceding crop or as a crop to be grown on infested soil to eliminate this brown root-rot condition are not sufficient, to date, to warrant recommendation for such purposes. With these facts in mind, the practical solution at present appears to be the continuous culture of tobacco, avoiding rotation when it is not necessary for other reasons.

PUBLICATIONS

General Bulletins

231 The Market Outlet for Massachusetts Apples. Jefferson, Lorian P. 40 p. January, 1927.

This deals with the wholesale and retail distribution in domestic markets, with some discussion of the character of the demand. The world crop and international trade are also discussed, and the costs and problems of exporting. Seasonal fluctuations in Baldwin apple prices, 1889-1925, and comparisons of Baldwin and McIntosh prices are included, with a discussion of the relation between price and size of the apple crop. The chief conclusions are that the demand for New England apples is increasing in New England markets, and that the demand for good quality and larger sizes is increasing.

232 Effect of Potash Salts on Crop Yields. Haskell, Sidney B. 10 p. February, 1927.

Among the more important results of long-continued experiments comparing chemical forms of fertilizer potash are the following: occasionally better table quality of potatoes, but seldom any significant difference in yields; variations in the stand of grass and clover, but surprising similarity in yields of hay; a distinct difference in the winterkilling of cane fruits, with consequent large differences in yield; no indication of sulfur shortage even after thirty years of treatment with little or no sulfur in the fertilizer, and a similar result with magnesium.

233 The Codling Moth in Massachusetts. Bourne, A. I. and Whitcomb, W. D. 19 p. March, 1927.

The life history of the codling moth in Massachusetts was studied for three consecutive seasons. The codling moth has one complete generation and a partial second annually in this State. There is a slight overlapping of the two generations, so that from the time the fruit is set until harvest there are but few days when infestation may not take place. Spraying is the most important phase of codling moth control and should be thorough and timely. The calyx spray and the post calyx sprays are the most important in the control of this insect. The material most effective against the codling moth is arsenate of lead, and its use is recommended at the rate of 1½ pounds of the powder in 50 gallons of water.

234 The Poisoning of Honey Bees by Orchard Sprays. Bourne, A. I. 12 p. March, 1927.

The experiments indicate that, if the recommended combination of lead arsenate, lime-sulfur and nicotine sulfate is used, spraying should have no appreciable effect upon colonies of bees not subject to any restrictions of flight. This is true even when some bloom is present, unless improperly timed spraying is carried out on a large scale.

235 Farm Taxes and Assessments in Massachusetts. Yount, Hubert W. 36 p. April, 1927.

Farm real estate on 214 farms in 1923 was assessed at 53 per cent of the owners' valuation. The average ratio of the assessed value of farm real estate to the owners' valuation varies as much as 20 per cent between towns; and also varied widely between farms in the same town. Livestock was assessed at 65 per cent of its value as reported by the owners. Reports from 133 boards of assessors show wide differences between towns in the estimated assessed value of land of a similar quality and use, and little uniformity in the assessment of livestock. Urban and industrial real estate is assessed at a higher percentage of value than farm real estate. In 1923 taxes on 207 farms took 9.76 per cent of the farm income before paying taxes. When computed on a similar basis, taxes take a larger share of the Massachusetts farmer's income than of the incomes received by certain other industrial or professional classes.

236 The Milk Supply of Massachusetts. McFall, R. J. 13 p. May, 1927.

I. Local Production and Imports. Data are presented showing that out of a total of slightly over 680 million quarts of milk used in Massachusetts, 59 per cent is produced in the State, 43 per cent imported, and 2 per cent exported. Practically all of the cream is imported. II. Consumption and Sources of Supply in Springfield and Vicinity. Figures show that this area produces 22 per cent of its supply of fluid milk, brings in 44 per cent from other states, and obtains 34 per cent from other parts of Massachusetts. III. Milk Production and Shipped-in Feed. For New England as a whole, 23 per cent of the milk production is based upon outside feed, and 77 per cent on home-grown supplies; for Massachusetts the corresponding figures are 30 per cent and 70 per cent respectively. New England's dependence upon outside feedstuffs is not unduly high when compared with the situation in some of the leading dairy nations of Europe.

237 Liming Onions. Jones, J. P. 7 p. October, 1927.

A report of observations made on the use of lime for onions in the Connecticut Valley. Onions were found to yield best on the less acid soils. For any degree of acidity the yield following tobacco averaged poorer than following onions. The best yields were secured at soil reactions of pH 6.0 and above. In applying lime for onions it was pointed out that other crops that might be grown on the land subsequently should be kept in mind. For example, lime, applied in amounts most beneficial to onions, has been proven harmful to tobacco.

238 Head Formation in Apple Trees. Shaw, J. K. 30 p. October, 1927.

A report of the effects on young apple trees of six different types of pruning. Results are given in terms of growth and early yield, and a series of tracings from photographs shows the effects on the development of individual trees. Directions are given for pruning young apple trees from the time they are set until the type of tree is established.

239 Cape Cod Cranberry Insects. Franklin, H. J. 67 p. February, 1928.

Worms and wormlike forms that attack the foliage, buds, flowers and fruit of the cranberry vine in this State are described, and methods for control discussed. The work is based on many years study and experience in the Cape Cod cranberry section. An important feature of the bulletin is the colored plates and other illustrations showing the cranberry insects in their different stages as well as the various ways in which they injure the plant.

240 Factors Affecting Returns from Potatoes in Massachusetts. Mighell, Ronald L. 27 p. January, 1928.

A survey of 54 farms in four different areas in the State is the basis of this bulletin. Potatoes occupied an average of 11 to 13½ per cent of the total crop land. The maximum, minimum and average hours of labor, by operations, the distribution of labor throughout the season, the amount of materials used and the production per acre for each of the four areas are given. A brief study of the effect of machinery on labor requirements and costs is presented.

241 Food Consumption of Rural School Children in Relation to Their Health. Davies, Esther S. 51 p. March, 1928.

A field study was made of two Massachusetts rural towns, to ascertain what relationships, if any, could be demonstrated between the dietary habits of children of elementary school age and their state of health. The investigation included visits to the homes of the children, inspection of school lunches, and dental and medical examinations. The study showed that most of the diets were of poor quality from the standpoint of the nutritional needs of the child. The most outstanding difference between the children of the two towns was in the condition of their teeth. The excellence of the teeth of one group as compared with the other is believed to have as its chief causal factor the high consumption of milk in the former town and the low milk utilization of the latter.

242 Vigor in Production-Bred Flocks. Hays, F. A. and Sanborn, Ruby. 26 p. April, 1928.

In pedigree breeding for high fecundity, the question of vigor is of paramount importance, because the mortality rate tends to become higher as egg production increases. In the Rhode Island Red flock studied, vigor was found to be independent of the fecundity traits, early maturity, high intensity, non-pause and high persistency; but to be reduced by eliminating broodiness. The most feasible practice for improving vigor is to breed only from those families showing the lowest mortality of pullets in the laying houses.

243 The McIntosh Apple on the New York Market. Jefferson, Lorian P. 12 p. May, 1928.

Data are presented showing the demand for McIntosh apples in New York City, the total volume received from the different sections producing McIntosh, and a comparison of the prices received for McIntosh from the different sections. Two conclusions seemed justified: The demand for McIntosh in New York has never been supplied, and the testimony of dealers indicates that the market will absorb many times what it now receives; the New England McIntosh are in general equal to any that are received in New York, as indicated by the prices received. A carlot of apples, shipped from New England to New York in the spring of 1928 was traced to the consumer to learn how the shipment was handled, how widely the apples were distributed, how many jobbers and retailers were concerned with the distribution, and the type of consumers to whom they were finally sold. The details of this shipment are reported.

244. Type-of-Farming Areas in Massachusetts. Mighel, Ronald L. and Brown, Marian. 16 p. June, 1928.

This study was made as a basis for future investigational work, and because a knowledge of existing farm conditions and how they have developed is essential to wise farm planning and administration. The bulletin defines thirteen different areas on the basis of soil, topography and type of farming, and shows in both graphical and descriptive form the distribution of the principal crop and live stock enterprises in the State according to the United States Census of 1925.

245. Blight and Leaf-spot of Carrot in Massachusetts. Doran, W. L. and Guba, E. F. 9 p. June, 1928.

The economic importance, causes and control measures of these diseases are discussed. The use of fungicides in the field is warranted only in the most rainy seasons. Crop rotation is of some value as a control, but seed treatment is not.

√ 246 Control of Red Spider and Powdery Mildew on Greenhouse Cucumbers. Whitcomb, W. D. and Guba, E. F. 16 p.

Effective treatments for controlling red spider and powdery mildew individually on greenhouse cucumbers have been developed. White mineral oil emulsion and sulfur, which are recognized as the most effective materials for controlling red spider and powdery mildew respectively, are not compatible. The proper choice of fungicides for controlling powdery mildew when white mineral oil emulsion is used is suggested. In addition, the nature, method, and rate of application of fungicides are considered in relation to the health of the foliage, weather conditions, and the location of the fungus.

Technical Bulletins

11 Intensity or Rate of Laying in Relation to Fecundity. Hays, F. A and Sanborn, Ruby. 16 p. November, 1927.

One of a series of bulletins dealing with inherited traits in relation to fecundity in the Rhode Island Red breed of domestic fowl. Intensity is an inherited trait which vitally affects fecundity. In this study four measures of intensity have been used: first sixty-day egg record, mean size of winter clutch, net winter rate of laying, and annual rate of laying. From the standpoint of the breeder, mean size of winter clutch is the most satisfactory criterion of intensity because it can be accurately determined and because it is inherited.

12 Net Correlations of Characters Concerned in Fecundity. Hays, F. A. and Sanborn, Ruby. 9 p. December, 1927.

This bulletin completes the series dealing with the five inherited traits concerned with fecundity in the Rhode Island Red breed of domestic fowl. Net correlations are presented, which more adequately portray the relative importance of the several characters than do the simple correlations previously used. Annual egg production is shown to be entirely independent of age at first egg; to be dependent to an important and substantially equal degree upon length of winter pause, intensity as measured by winter clutch size, and degree of broodiness; but to be most intimately affected by annual persistency. The multiple correlation of +.8642 shows that the five characters here considered largely control the annual egg yield.

13 Washing Powders for Dairy Use. Phillips, A. W., Mack, M. J., and Frandsen, J. H. 10 p. May, 1928.

1. Analyses of many washing powders on the market show four general classes, containing carbonate, caustic, phosphate and soap respectively.
2. There is very slight variation in those powders which come in the same class.
3. Laboratory and plant tests on these powders, on other mixtures, and on the pure ingredients have demonstrated the specific roles played by each ingredient.
4. A desirable composition for general dairy use has been indicated to be 60 per cent sodium carbonate and 40 per cent tri-sodium phosphate.
5. By buying the commercial chemicals the price per pound of cleaner may be reduced to close to 2 cents as compared with from 8 to 16 cents now paid for a similar grade of product.
6. The washing efficiency of the powders increased up to about 140° F. Below 95° F. the bactericidal action is greatly reduced.
7. All powders showed disinfecting powers in 0.6 per cent solution, by rendering the wash water sterile.

14 Cutaneous Immunity in Relation to Contagious Epithelioma. Pyle, Norman J. 16 p. June, 1928.

A serological study of birds immune to bird pox, a study of cutaneous immunity in relation to the disease, and the development of an efficient cutaneous vaccine for the treatment of the disease are reported.

15 The Extraction of Apple Juices in the Manufacture of Jelly. Fellers, Carl R. 35 p. June, 1928.

This investigation was an attempt to establish certain principles leading to greater economy in production, and providing a sounder basis for the housewife and commercial preserver for the manufacture of a uniformly high quality product. In general, two short (15-minute) successive extractions were desirable in order to obtain an optimum yield of juice containing sufficient pectin and acid to give satisfactory yields of high quality jelly. When only one extraction of the fruit was made there was a serious loss in jelly yield. Long extraction periods were unsatisfactory because of destruction of the jellying power of the pectin. The best results were obtained with a ratio of 1½ or 1 part of fruit to each part of water added. An extraction temperature of 212° F. was found most economical and effective. Red Astrachan, Red Siberian Crab, King David, Winesap and McIntosh were among the more suitable varieties for apple jelly manufacture. The development of a method of testing the consistency of jellies is described and the instrument pictured.

Circulars

74 Report of Progress in Tobacco Investigations. Jones, J. P. 8 p. April 1927.

The results obtained during the first three years of an experiment comparing different cropping systems for tobacco are presented. Tobacco grown in rotation with (1) corn and hay, (2) potatoes and onions, (3) corn, (4) hay, (5) potatoes, and (6) onions, was compared with tobacco grown every year on the same land (1) with fertilizer only, (2) with fertilizer and manure, and (3) with fertilizer and timothy cover crop. Tobacco grown in continuous culture proved better than that grown in any other cropping system; tobacco receiving manure and fertilizer better than that with fertilizer only; tobacco without a cover crop much better than that with a cover crop, or that grown in any of the rotations except with onions.

Control Bulletins

39 Control of Bacillary White Diarrhea, 1926-27. Van Roekel, Henry. 7 p. July, 1927.

40 Inspection of Commercial Feedstuffs. 27 p. November, 1927.

41 Inspection of Commercial Fertilizers. Haskins, H. D., Walker, L. S. and Goodwin, M. W. 37 p. December, 1927.

42 Inspection of Agricultural Lime Products. Haskins, H. D., Goodwin, M. W. and Kuzmeski, J. W.

43 Control of Salmonella Pullorum Infection (Bacillary White Diarrhea) 1927-28. Hinshaw, W. R. and Sanders, E. F. 22 p. July, 1928.

Meteorological Reports

457-480, inclusive. Monthly reports giving daily weather records with monthly summaries.

Scientific Contributions

53 Physical Character of Eggs in Relation to Hatchability. Hays, F. A. Poultry Science 6:196-200. April-May, 1927.

54 The Discoloration of Canned Cranberries. Morse, Fred W. Jour. Agr. Research 34:889-892. May 1, 1927.

55 Solubility of Copper Sulphate, Malachite and Burgundy Precipitate in Ammonium Hydroxide, Carbonate and Bicarbonate. Holland, E. B. and Gilligan, G. M. Jour. Phys. Chem. 31:728-741. May, 1927.

56 Relation of Age of Parents to Hatchability, Livability and Fecundity in Domestic Fowl. Hays, F. A. Poultry Science 7:106-115. March, 1928.

57 Public Health Aspects of Food Preservation. Fellers, C. R. Jour. Public Health, 17:470-475. 1927.

58 A Volume Weight Study of Ice Cream. Phillips, A. W. Jour. Dairy Sci. 10:232-249. May, 1927.

59 Reducing the Cost of Nicotine Sulphate Sprays. Worthley, H. N. Jour. Econ. Ent. 20:615-625. Aug., 1927.

60 Influence of Form and Proportion of Lime Used and of Method of Mixing on the Resulting Bordeaux Mixture. Holland, E. B., Dunbar, C. O. and Gilligan, G. M. Jour. Agr. Research 34:677-686. April 1, 1927.

61 Some Observations on Root and Crown Bud Formation in Asparagus Officinalis. Tiedjens, V. A. Proc. Amer. Soc. Hort. Sci. 23:189-196. 1926.

62 Some Observations on the Response of Greenhouse Cucumber (Cucumis sativus) to Certain Environmental Factors. Tiedjens, V. A. Proc. Amer. Soc. Hort. Sci. 23:184-189. 1926.

63 The Inheritance of Persistency and Its Relation to Fecundity. Hays, F. A. Proc. World's Poultry Congress. 1927. (3 p.)

64 Chemical Hydrated Lime for the Preparation of Bordeaux Mixture. Holland, E. B., and Gilligan, G. M. Phytopathology 17:571-572. Aug. 1927.

65 Relation between Water and Potash in Plant Production. Morse, Fred W. Jour. Agr. Research. 35:939-946. November 15, 1927.

66 Percentage of Sugar and Starch as Influenced by Preparation of Material. Jones, C. P. Proc. Amer. Soc. for Hort. Sci. 24:205-206. 1927.

67 Calf Meal Studies. I. Laboratory Experiments in the Improvement of Physical Condition. II. Feeding Experiments with Cooked and Uncooked Meal. Archibald, J. G. Jour. Dairy Science. 11:119-135. March, 1928.

68 Relation of the Adjustment of Soil Reaction to Black Root-Rot of Tobacco. Doran, W. L. Science 66:661-662. December 30, 1927.

69 Tin Cans and Glass Jars as Bacterial Contaminants in Canned Food. Fellers, Carl R. Amer. Jour. Public Health. 18:763-770. June, 1928.

70 Acetic Acid as a Soil Disinfectant. Doran, W. L. Jour. Agr. Research 36:269-280. February 1, 1928.

71 An Experiment in Trapping Cutworms. Whitcomb, W. D. Jour. Econ. Ent. 21:592-598. August, 1928.

72 The Growth of Tobacco and Brown Root-Rot of Tobacco as Affected by Timothy Infusions of Different Ages. Doran, W. L. Jour. Agr. Research 36:281-287. February 1, 1928.

73. Sex Ratios in Cucumber Flowers as Affected by Different Conditions of Soil and Light. Tiedjens, V. A. Jour. Agr. Research 36.721-746. April 15, 1928.

74. Electrolytic Apparatus for the Determination of Copper in Insecticides and Fungicides. Holland, E. B. and Gilligan, G. M. Jour. Indus. and Eng. Chem. 20:533-535. May, 1928.

75 Some Observations on Mutations in Deciduous Fruits. Drain, Brooks D. Proc. Amer. Soc. for Hort. Sci. 24:147-148. 1927.

76 Classification of Copper Fungicides. Holland, E. B. and Gilligan, G. M. Phytopathology 18:455-458. May, 1928.

77 The Relation of Environment to Shape of Fruit in Cucumis Sativus L. and Its Bearing on the Genetic Potentialities of the Plants. Tiedjens, V. A. Jour. Agr. Research 36:795-809. May 1, 1928.

78 Jelly-Strength Measurements of Fruit Jellies by the Bloom Gelometer. Fellers, Carl R. and Griffiths, Francis P. Jour. Indus. and Eng. Chem. 20:857-862. August, 1928.

79 Influence of Cropping Systems on Root-Rots of Tobacco. Jones, J. P. Jour. Amer. Soc. Agron. 20:679-685. July, 1928.

80 The Iodine Content of Cape Cod Cranberries. Morse, Fred W. Jour. Biol. Chem. 79:409-411. October, 1928.

81 Control of Cucumber Powdery Mildew in Greenhouses. Guba, E. F. Phytopathology 18:847-860. 1928.

Nitrate Accumulation under a Mulch. Beaumont, A. B., Sessions, A. C. and Kelly, O. W. Soil Science 24:177-184. 1927.

Assimilation of Fixed Nitrogen by Tobacco. Beaumont, A. B. Science 66:237. 1927.

Method of Growing Small-seeded Plants under Sterile Conditions. Beaumont, A. B. and Larsinos, G. J. Science 66:350. 1928.

Nitrification in Massachusetts Soils. Beaumont, A. B. Proceedings of the First International Congress of Soil Science 3:240-249.

The Checker-board Method of Laying out Plots. Jones, J. P. Jour. Amer. Soc. Agron. 20:400-402. 1928.

Spray Solutions and the Control of Apple Scab. Butler, O. and Doran, W. L. N. H. Agr. Expt. Sta. Tech. Bul. 36. 1928.

False Blossom. Franklin, H. J. Wisconsin State Cranberry Growers' Assoc., 41st Ann. Rept. 1928. pp. 10-16.

The Digger Wasps of North America of the Genus Podalonia (Psammophila). Fernald, H. T. Proceedings U. S. Nat. Mus., v. 71, Art. 9, 1927. 39 p. 2 pl.

Insects: the People and the State. Fernald, H. T. Scientific Monthly, Vol. 27, 1928. 13 p.

Insect Pests in Massachusetts Orchards. Bourne, A. I. Mass. Fruit Growers' Assoc. Rept. 1927.

Recent Studies on the Codling Moth in Massachusetts. Bourne, A. I. Conn. Pomological Soc. Rept. 1927.

Honey Bee Poisoning by Sprays. Bourne, A. I. Science, October, 1927.

Orchard Insect Pests of 1927: The Problem of Spray Residue in Massachusetts: Railroad Worm Observations. Bourne, A. I. Mass. Fruit Growers' Assoc. Rept. 1928.

Non-gaseous Spoilage in Canned Marine Products. Fellers, C. R. Univ. of Wash. Publications in Fisheries, Vol. 1, No. 11, p. 229-238. Oct., 1927.

Canned Foods and the Public Health. Fellers, C. R. Amer Jour. Public Health 18:893-896. July, 1928.

Some Common Poultry Diseases. Hinshaw, W. R. Biennial Report, Northeastern Tuberculosis Conference.

Bacillary White Diarrhea. Hinshaw, W. R. and Sanders, E. F. Vet. Medicine 23:219-220. 1928.

CHANGES IN STAFF, DECEMBER 1, 1926 to NOVEMBER 30, 1928.

Appointments.

Barton, Rena L., Laboratory Assistant, Pomology, August 1, 1928.

Brown, Marian V., A. B., Laboratory Assistant, Farm Management, March 1, 1927.

Church, Cornelia B., B. S., Laboratory Assistant, Home Economics, July 1, 1928.

Clarke, Miriam K., B. A., Laboratory Assistant, Poultry Disease Elimination Law, September 1, 1927.

Davies, Esther S., Ph B., B. S., Assistant Research Professor and Head of Department, Home Economics, January 1, 1927.

DeRose, H. Robert, M. S., Assistant Chemist, Feed and Fertilizer Laws, October 1, 1927.

Dufresne, Virginia R., A. B., Laboratory Assistant, Agricultural Economics, July 1, 1927.

Dunlap, Glenn L., D. V. M., Assistant Veterinary Pathologist, Pathology Service Laboratory, June 15, 1928.

France, Ralph L., M. S., Assistant Bacteriologist, Bacteriology Service Laboratory, July 1, 1928.

Fuller, James E., A. B., A. M., Assistant Research Professor, Bacterioloy and Physiology, July 1, 1928.

Griffiths, Francis P., B. S., Research Assistant, Horticultural Manufactures, September 1, 1927.

Gunness, Christian I., B.S., Meteorologist, March 1, 1928.

Hinshaw, William R., V. D. M., M. S., Chief of Laboratory, Poultry Disease Elimination Law, July 21, 1927.

Hopkins, Elizabeth F., M. S., Seed Analyst, Seed Law, September 1, 1927.

Kelley, Joseph L., Technical Assistant, Cranberries, December 1, 1926.

Kelly, Oliver W., M. S., Senior Seed Analyst, Seed Law, July 1, 1928.

Kuzmeski, J. W., B. S., Junior Chemist, Feed and Fertilizer Laws, June 4, 1927.

Mighell, Ronald L., M. S., Assistant Research Professor, Farm Management, January 1, 1927.

Nelson, Paul R., M. S., Research Assistant, Plant and Animal Chemistry, December 1, 1926.

Nickerson, Elsie E., B. S., Technical Assistant, Home Economics, January 1, 1928.

Rozman, David, Ph. D., Assistant Research Professor, Agricultural Economics, December 1, 1927.

Sanders, Ellmore F., D. V. M., Assistant Veterinary Pathologist, Poultry Disease Elimination Law, September 15, 1927.

Sievers, Fred J., M. S., Director, February 1, 1928.

Snell, Moses E., Technical Assistant, Agronomy, September 1, 1927.

Van Meter, Ralph A., B. S., Professor, Pomology, April 1, 1928.

Wright, Kenneth E., M. S., Assistant Research Professor, Dairy Manufactures, May 1, 1928.

Resignations.

Haskell, Sidney B., B. S., Director, December 15, 1927.

Hopkins, Elizabeth F., M. S., Seed Analyst, Seed Law, May 19, 1928.

Horne, Robert S., B. S., Research Assistant, Agronomy, August 31, 1927.

Kokoski, Frank J., B. S., Analyst, Feed and Fertilizer Laws, May 18, 1927.

Rowley, Harold F., B. S., Technical Assistant, Veterinary Science, June 30, 1927.

Prescott, Lelia, Analyst, Poultry Disease Elimination Law, August 31, 1927.

McFall, Robert J., Ph. D., Research Professor, Aricultural Economics, June 30, 1927.

Nickerson, Elsie E., B. S., Technical Assistant, Home Economics, May 1, 1928.

Ostrander, John E., A. M., C. E., Meteorologist, March 1, 1928.

Phillips, Arthur W., A.M., Assistant Research Professor, Dairy Manufactures, July 31, 1927.

Van Roekel, Henry, M. S., D. V. M., Specialist, Poultry Disease Elimination Law, July 15, 1927.

Walker, Lewell S., B. S., Assistant Official Chemist, Fertilizer Law, June 15, 1927.

PUBLICATION OF THIS DOCUMENT APPROVED BY
THE COMMISSION ON ADMINISTRATION AND FINANCE

2500-5-'29. No. 5677

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 248 March, 1929

Tomato Leaf-Mold
The Use of Fungicides for Its Control in Greenhouses

By E. F. Guba

The culture of greenhouse tomatoes is an important industry in Massachusetts, and the area devoted to this crop has increased considerably in recent years. Leaf-mold is the most serious disease affecting the crop. The loss of one to two months of pickings of the fall crop and one month of the spring crop as the result of this disease is common. Past recommendations regarding the proper choice of fungicides for its control are conflicting and not based on experimental evidence, and growers who have used fungicides have not obtained control. This investigation has considered the merits of different types of fungicides. An effective material, and a practical method of application, have been discovered which are recorded in this bulletin.

Requests for Bulletins should be addressed to the

AGRICULTURAL EXPERIMENT STATION,
AMHERST, MASS.

TOMATO LEAF-MOLD

THE USE OF FUNGICIDES FOR ITS CONTROL IN GREENHOUSES[1, 2]

By E. F. Guba, Assistant Research Professor of Botany

INTRODUCTION

Tomato leaf-mold caused by the fungus *Cladosporium fulvum* Cke. is the most serious disease of greenhouse tomatoes in Massachusetts. Relatively little experimental work has been done to determine the effect of fungicides on the disease, yet there is recommended in the literature a variety of materials the efficacy of which is unsupported by published evidence. Commercial growers have tried most of the materials suggested without success. Experimental work with fungicides in greenhouses has not received much recognition largely because successful control of this disease has been considered a matter of proper management of ventilation and heating. In establishments where management might successfully be practiced it usually fails.

REVIEW OF LITERATURE

An effective fungicide for this fungus has been a much discussed subject among pathologists. The earlier literature on the subject has been reviewed by Makemson (22). Previous to his study of the fungus some authorities recommended copper mixtures and others sulfur, while others were unable to obtain results with either group of fungicides. Makemson found from spore toxicity tests that Bordeaux mixtures, ammoniacal copper carbonate and potassium sulfide were entirely ineffective and that formaldehyde at the rate of 1 ounce of a 40 per cent solution to 2½ gallons of water (.12 per cent) and self-boiled liquid lime-sulfur were toxic while commercial liquid lime-sulfur 2.5 per cent showed promise. His control work on tomato plants substantiated the results of his spore toxicity tests with Bordeaux mixtures, likewise showed lack of value of sulfur dust and formaldehyde and the slight superiority of commercial and self-boiled lime-sulfur. Makemson's work left the impression that Cladosporium is not as susceptible to copper as to sulfur. This is unfortunate, for his results from self-boiled and concentrated lime-sulfur solutions were too meagre and conflicting to afford an accurate estimate of their value, and dusting sulfur proved of no value at all. Williams (38) reported that sulfur suspensions, colloidal sulfur, sodium polysulfide 2.5 per cent, potassium sulfide .5 per cent, ammonium polysulfide .5 per cent, Cheshunt Compound .5 to 2 per cent, copper silico-fluoride .2 to .5 per cent, nickel silico-fluoride .5 per cent, and barium silico-fluoride (sat. sol.) prevented germination while sodium polysulfide .5 to 1 per cent and lime-sulfur .5 to 2 per cent permitted germination. Of the materials which prevented germination, only potassium sulfide, ammonium polysulfide and Cheshunt Compound .5 to 1 per cent proved safe to tomato foliage, but when applied to infected leaves none affected the viability of the spores. Neither Makem-

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[1] The writer is indebted to Professor A. Vincent Osmun, Head of the Department of Botany for valuable suggestions and criticisms in the preparation of the manuscript of this Bulletin.

[2] The information in this bulletin is based on the results of experiments conducted by the writer at the Market Garden Field Station, Waltham, and in commercial greenhouses in eastern Massachusetts.

son nor Williams stated the temperatures under which the tests were conducted and both failed to consider the possible relation of temperature to the activity of sulfur compounds. Parker (27) reported good results with ammoniacal copper carbonate wash. Alvesco mildew powder, a copper and sulfur dust of English manufacture, was recommended by A. M. D. (7), Parker (27) and Dyke (8).

Hasper (12) compared sulfur, copper salts and Uspulun and reported best results with .5 per cent Uspulun applied at 8 to 10 day intervals. In an anonymous paper (1) from Holland, Uspulun .5 per cent and Solbar 1 per cent were reported to give effective control. Solbar caused foliage burning but Uspulun none. Triebels (33) advised treatments with .5 per cent Uspulun beginning with the first appearance of leaf-mold and repeating at 2 to 3 week intervals up to the time the fruit becomes large. Since the fruits acquire the taste of phenol at this period, he advised using 1 per cent Solbar for subsequent treatments. Hofferichter (13) obtained good control with 1 per cent Solbar. Baehr (2) compared Bordeaux, Cosan and Solbar and reported that Solbar alone gave excellent control, while the other materials were of no account. Jonassen (18) advised spraying every fourteen days with 1 to 1.5 per cent Germinal or Uspulun beginning when the houses are set, and with a 5 per cent solution if the disease is already present.

Sulfuring of the heating pipes has been recommended for combating Cladosporium by Massey and Rhodes (23) and Parker (27). Manufactured devices for vaporizing sulfur, such as Campbell's Patent Sulfur Vaporizer and the Rota-Generator, have been recommended for controlling Cladosporium by Bewley (6) and A. M. D. (7), but Baehr (2) reported no control with the Rota-Generator.

As the literature reveals, many materials have been suggested. The recommendations concerning the choice are contradictory and inconsistent, and those materials which have been reported of merit are unsupported by adequate evidence. It has seemed desirable, therefore, to determine the merits of different fungicides in the control of this disease.

LABORATORY CONTROL WITH FUNGICIDES

Effect of Fungicides on Spore Germination

The technique employed by Makemson (22) and Williams (38) for determining the effect of fungicides on the germination of Cladosporium spores is contrary to natural methods of dissemination of the fungus and inoculation of the plants in the greenhouse. Makemson applied spores in water drop suspensions to glass surfaces bearing dry deposits of the fungicide, and spores in drops of the fungicide on clean cover glasses. The results by both methods of study were identical. Williams applied water suspensions of spores to glass surfaces bearing dry deposits of the fungicide.

Cladosporium spores are capable of germinating in moisture saturated air and in the absence of the water drop. Spores are dispersed in the greenhouse through the medium of the air and in the dry state, being liberated by disturbing leaves affected with mold. The common practice of tapping the plants with sticks to assist pollination of the flowers is a means of producing spread and epidemics of disease. Under the usual conditions of growing greenhouse tomatoes water is not a carrier of the inoculum. In determining the merits of fungicides for preventing infection, obviously the logical technique to follow is that of applying dry spores to dry fungicidal deposits and of exposing dry spores to contact with dusts or liquids, drying, and then exposing the slides to optimum conditions for spore germination. For tests here reported various methods of technique were considered with the view of determining under what conditions control could be expected. The tests were conducted at different degrees of temperature. An outline of the methods of technique used follows:

Method I. Dry spores were applied with a camel's hair brush to glass slides bearing a dry covering of fungicide. This method of technique simulates most closely the conditions obtained on sprayed foliage and offers the most satisfactory means of determining the efficacy of the dry chemical residue in protecting the foliage from infection.

Method II. Dry spores were applied to clean glass slides which were subsequently dusted or sprayed. The spray was permitted to dry previous to incubation.

Method III. Technique was similar to II except that slides were incubated wet. By methods II and III the efficacy of the sprays as disinfectants was demonstrated, and by II the merits of the dust in preventing germination.

Method IV. Water drop suspensions of spores were placed on slides covered with the dry fungicide. Where fungicidal activity occurs under the conditions surrounding this method of technique it may be inferred that affirmative results can be expected on wet foliage in the greenhouse.

Method V. Glass slides brushed with dry spores were inverted and rested at a distance of 3 mm. above the dry fungicide. This method served to demonstrate the merits of the fungicide as a fumigant.

Spraying and Dusting Materials.

Study of Table 1 reveals significant data bearing upon the control of the disease with fungicides, not considered in previous investigations. As the data show, dusting sulfurs are of no value in preventing germination by any of the methods of testing and under the range of temperatures considered. The data supports Makemson (22) who showed that sulfur dust is of no value, but are contrary to the results of Williams (38) which show that sulfur suspensions and colloidal sulfur are toxic. Barker, Gimingham and Wiltshire (4) reported that Cladosporium is not nearly as sensitive to sulfur as other fungi. These studies show that sulfur dusting materials are not effective and cannot be expected to offer control of the disease.

Some toxicity was manifested by Hammond's Grape Dust against spores conveyed in the water drop. This was due to its copper content. The composition of Grape Dust is sulfur 64 per cent, copper sulfate 2.5 per cent, and inert material not more than 33.5 per cent.

Hammond's Slug Shot did not control germination in contact with dry spores but in water drops abnormal germ tubes resulted. Hammond's Slug Shot contains gypsum and free sulfur, calcium hydroxide, silica, iron and aluminum oxides, arsenic, less than 1 per cent of metallic copper, less than 2 per cent of organic material and traces of nicotine and carbolic acid.

Schloesing's sulfur, a dusting mixture recovered in the manufacture of artificial gas, also failed under every method of technique. It is a finely divided product and easily wet with water. According to analyses there is present 36.42 per cent total sulfur in the original and 25.44 per cent sulfur in carbon bi-sulfide extract. The ash is highly colored with iron oxide (Fe_2O_3). The material also contains phenols and cyanides.

Herbert and Herbert colloidal sulfur failed by every method of study used to control germination. The concentrated product is strongly acid. A 5 per cent mixture is not toxic.

Table 1. Toxicity of Fungicides to Germinating Spores.

FUNGICIDE	I Dry spores applied to dry residue			II Dry spores treated with fungicide; incubated dry			III Same as II but incubated wet			IV Water suspension of spores applied to dry residue		V Dry spores exposed to fungicide at a distance	
	70°	80°	90°	70°	80°	90°	70°	80°	90°	70°	80°	70°	90°
Anchor Brand Sulfur Dust				+	+	+				+	+	+	+
Niagara Kolo Dust				+	+	+				+	+	+	+
Ortho Sulfur Dust				+	+	+				+	+	+	+
Trick Sulfur				+	+	+				+	+	+	+
Hammond's Grape Dust				+	+	+				+*	+*	+	+
Hammond's Slug Shot				+	+	+				+*	+*	+	+
Schloesing's Sulfur				+	+	+				+	+	+	+
H. & H. Colloidal Sulfur 5%	+	+	+	+	+	+				+	+	+	+
Lime-Sulfur 10%	+	+	+	+*	+*	+*	+*	+*	+*	+	—	+	+
Lime-Sulfur 1%	+	+	+	+	+	+	+	+	+	+	+	+	+
Potassium Sulfide .08%	+	+	—	+	+	—	+	+	—	+	+	+	+
Potassium Sulfide .4%	+	—	—	+*	—	—	+*	—	—	—	—	+	+
Solbar 1%	+	+	+	+	+*	+*	+*	+*	+*	+	+	+	+
Sulfuric Acid .05%	—	—	—	—	—	—	—	—	—	—	—	+	+
Sulfuric Acid .025%	—	—	—	—	—	—	—	—	—	+	+	+	+
Sulfuric Acid .02%	—	—	—	—	—	—	—	—	—	+	+	+	+
Naphthalene Dust				—	—	—				—	—	—	—
Naphthalene-Lime Dust 1-2				—	—	—				—	—	—	—
Schacht's Naphtal-Schwefel				—	—	—				—	—	+	+
Copper-Lime Dust 10-90				+	+	+				—	—	+	+
Copper-Lime Dust 14-86				+	+	+				—	—	+	+
Copper-Lime Dust 19-81				+	+	+				—	—	+	+
Niagara D-25 Copper Dust				+	+	+				—	—	+	+
Bordeaux 1-1-50	+	+	+	+*	+*	+*	—	—	—	—	—	+	+
Bordeaux 6-6-50	+	+	+	+*	+*	+*	—	—	—	—	—	+	+
Copper Sulfate .05%	+*	+*	+*	—	—	—	—	—	—	—	—	+	+
Copper Sulfate .04%	+*	+*	+*	—	—	—	—	—	—	—	—	+	+
Copper Sulfate .03%	+	+	+	+*	+*	+*	+*	+*	+*	+	+	+	+
Lime Dust				+	+	+				+	+	+	+
Semesan .2%	—	—	—	—	—	—	—	—	—	—	—	+	+
Uspulun .2%	—	—	—	—	—	—	—	—	—	—	—	+	+
Formaldehyde .4%	+	+	+	—	—	—	—	—	—	+	+	—	—
Formaldehyde .1%	+	+	+	—	—	—	—	—	—	+	+	+	+
Formaldehyde .04%	+	+	+	+	+	+	+	+	+	+	+	+	+
Burning Sulfur	—	—	—	—	—	—				—	—	—	—

+ germination; fungicide not effective.

— no germination; fungicide effective.

* germination considerably suppressed but fungicide not considered effective.

A 1 per cent solution of lime-sulfur was not effective. A 10 per cent solution showed merit by methods of study II and III. In the water drop (IV) at the higher temperatures germination was inhibited.

Potassium sulfide in a .08 per cent solution was toxic at 90° F. (I, II, III), but spores sown in a water drop were not affected at 70° and 80° F. A .4 per cent solution gave disinfection (II and III) at 80° and 90° F. Germination was controlled in the water drop (IV) and the dry residue (I) was toxic at 80° and 90° F.

Solbar is a sulfur powder. It contains about 35 per cent water soluble sulfur and the water solution contains chiefly barium tri-sulfide. The material was ineffective by methods of study I and IV but gave some control of germination when spores were wetted by the spray (II and III), especially at the higher temperatures. The data do not suggest that control of the disease can be expected from its use, although Hofferichter (13), Anon. (1), Baehr (2) and Triebels (33) have regarded the product as having merit.

Sulfuric acid of the specific gravity 1.835-1.840 in a .02 per cent solution was toxic to spores wetted by the spray and its residue was likewise toxic to dry spores (I). A .01 per cent solution was weakly fungicidal but its residue was inactive. A residue of a .05 per cent solution was lethal to spores applied in the water drop, but residues of weaker solutions were not effective.

Naphthalene flakes were placed in moist Petri dishes in which dry spores on slides were incubated for germination. The vapors emanating from the deposits were lethal. Naphthalene dust prepared by grinding naphthalene flakes was toxic in water and similar control was obtained with a naphthalene-lime dust containing 1 part of naphthalene and 2 parts of lime.

Schacht's Naphtal-Schwefel is the only dusting material encountered that proved effective by the two methods of study (II, IV). It appeared from these tests to be the most promising dusting material for combating leaf-mold. The product is manufactured in Germany and is recommended for surface mildews. It is a flesh colored powder, lacks the characteristic naphthalene odor and is not wettable with water. On warming or in water with sodium peroxide the naphthalene odor is noticeable. The material contains sulfur soluble in CS_2, sulfur by oxidation with Na_2O_2, combined naphthalene, CaO probably combined as hydrate and carbonate, and SiO_2, Fe_2O_3 and Al_2O_3. The naphthalene compound was not identified.

Dry spores dusted with copper powders (II) germinated normally, but when spores were applied in water drops to the copper deposit, germination was completely suppressed.

Bordeaux mixtures proved toxic when dry spores were wetted (III) and incubated immediately, but spores which escaped wetting were not affected. When the spray was allowed to dry previous to incubation (II) germination was not measurably affected. The germ tubes were observed to grow into the surrounding dry Bordeaux residue unaffected.

Copper sulfate in dilute solutions was toxic. Spores wetted with a .04 per cent solution of copper sulfate were killed and a dry residue of the same spray was lethal to spores applied in the water drop. Spores which escaped wetting (II and III) were not measurably affected. The dry residue of a .04 per cent solution exhibited toxicity to dry spores (I) but weaker dilutions did not.

Copper fungicides possess no merit in the absence of moisture. Williams (38) reported that copper salts are toxic in water and Makemson (22) claimed that Bordeaux mixtures and ammoniacal copper carbonate have little appreciable effect upon either germination or the growth of the germ tubes. In these studies, however, consistent control of germination in the water drop has been obtained. The results substantiate the effectiveness of copper materials on field tomatoes for combating Cladosporium reported by Edgerton and Moreland (10), Edgerton (9), Sherbakoff (30), and Weber and Ramsey (37). Moisture not only influences the growth of the fungus but also favors the activity of copper materials.

Lime dust was not toxic by either of the two methods of study (II and IV).

Organic mercury compounds were toxic to spores by methods of study I, II, III and IV. Uspulun was toxic at a .1 per cent strength. Semesan, at a .1 per cent strength, was not toxic to spores applied in the water drop to the dry residue (IV), but was toxic by other methods of study. The effectiveness of the organic mercury compounds by all methods of study suggests the possibility of their use to control infection in the greenhouse.

Commercial 40 per cent formaldehyde at dilutions ranging from 1-100 to 1-400 (.4 to .1 per cent) was lethal (II, III). Dry spores on slides were placed in dishes moistened with formaldehyde (V) but only 1-100 and stronger mixtures produced a lethal atmosphere. Since the 1-100 mixture is fungicidal in the air as well as in the soil, its use for soil sterilization is preferable to a 1-400 mixture. Formaldehyde was ineffective by methods of study I and IV, and a strength of 1-1000 was ineffective by every method of study. The data suggest that disinfection of the greenhouse may be obtained by the usual method of drenching the soil with a 1-100 mixture and closing the greenhouse tight after the treatment.

The toxicity of the fumes of burning sulfur was very striking. Spores on slides confined within Petri dishes placed in a treated atmosphere were killed. The data indicate that the burning of sulfur between crops, as is generally practiced by growers, is an effective and desirable means of destroying hibernating parts of the fungus.

Other than naphthalene, formaldehyde and burning sulfur, none of the materials listed in Table 1 were of any fungicidal value as fumigants.

The residues of potassium sulfide, copper sulfate, sulfuric acid, and organic mercury sprays showed a toxic effect to spores applied dry to the slides (I). By this method of study some solution of the residue in moisture deposited on the surface of the slides occurred. This fungicidal effect was shown only by readily soluble materials such as noted.

Vaporized Sulfur.

On heating sulfur, amorphous particles of sulfur are discharged into the air, float about, and finally are deposited on exposed surfaces. These amorphous particles of sulfur are fluid and spread over the surface on which they fall. The sulfur droplets are very sticky. This is considered to be due to the fluid property of the sulfur which in this condition is able to rid the surface of air films. Barker and Wallace (5) report that sulfur distributed through the atmosphere by its vaporization not only furnishes a much more complete superficial covering than can be secured by dusting or spraying, but also possesses a remarkable power of adhesion, withstanding the action of heavy rains or sprays of water of considerable force. To compare the relative adhesiveness of vaporized sulfur and pure dusting sulfur, ten glass slides, each of an area of 3 square inches, were weighed with a chemical balance then exposed to an atmosphere treated with vaporized sulfur and again weighed. Similarly ten weighed slides were dusted with a pure dusting sulfur and reweighed. Both sets of slides were exposed to a rain of .36 inches then air dried in the laboratory and again weighed to determine the amount of loss from washing. (Experiment A.)

The experiment was repeated (Experiment B), but the amount of rain recorded was .04 inches. The relative adhesiveness of the two sulfurs is indicated quantitatively in Table 2. The data show that washing caused an appreciable loss of dusting sulfur but that its effect upon vaporized sulfur was negligible.

The dry particles of amorphous sulfur measure 1 to 5 microns in diameter. The largest, which are aggregates of smaller droplets, reach a diameter of 24 microns. The distance between the particles varies according to the density of

Table 2. Comparative Loss of Vaporized Sulfur and Dusting Sulfur after Exposure to Rain.

	VAPORIZED SULFUR		DUSTING SULFUR	
	Experiment A	Experiment B	Experiment A	Experiment B
First weight of Sulfur, grams	.0528	.0591	.0620	.0464
Second weight of Sulfur, grams	.0510	.0579	.0054	.0252
Loss of Sulfur, grams	.0018	.0012	.0566	.0212
per cent	*3.4*	*2.0*	*91.3*	*45.7*

the deposit. Dense deposits show very little unoccupied space. Thin deposits show an extremely fine division of sulfur. In both cases distribution is extremely uniform (Plate I, C, D). The uniform distribution of vaporized sulfur on the plants and ground in the greenhouse is impressive. Such an intimate association between the fungus and sulfur is not obtainable with spraying or dusting materials (Plate I, A, B).

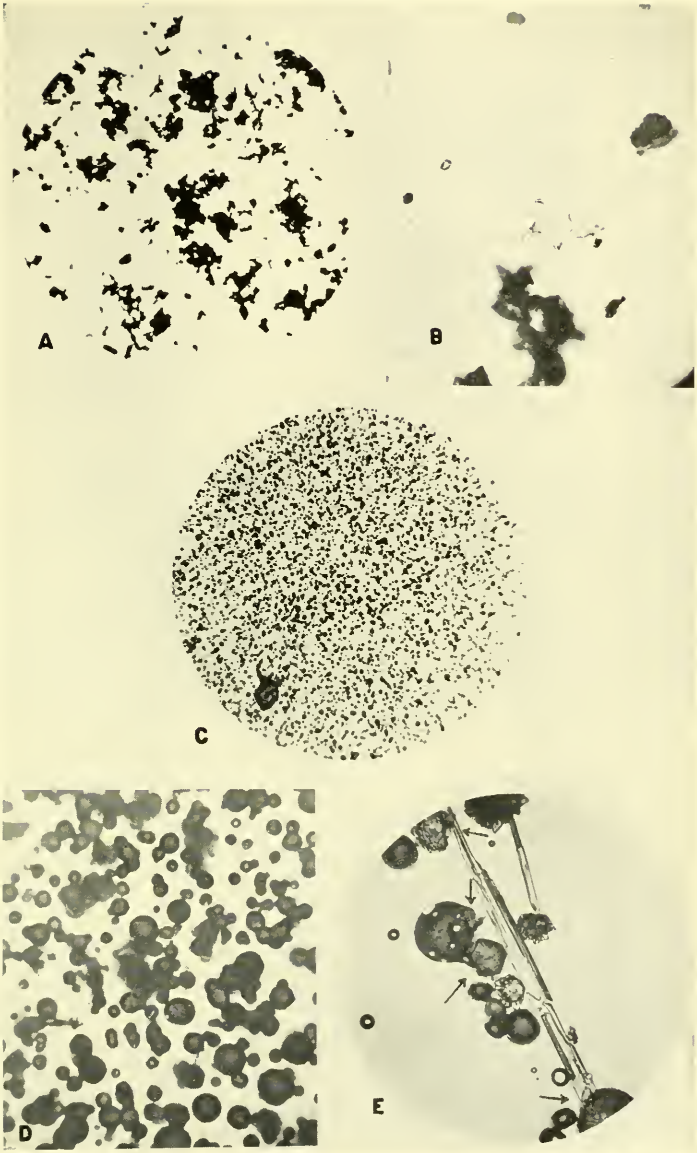
In a series of experiments, Cladosporium spores were exposed in different ways to sulfur vapors (Table 3) and then incubated for 48 hours in Petri dishes. The sulfur was evaporated slowly over an electric hot plate at moderate temperatures with free access to air. The spores were examined for germination at the termination of 48 hours and a final examination was made at the end of 72 hours. Duplicate slides were exposed, one group serving to determine the degree of acid present after exposure to sulfur vapors and the other after incubation. Constant chamber temperatures were maintained during the exposure of the spores to vaporized sulfur and during the period of incubation in Petri dishes. For these tests individual temperatures between 65° and 90° F. were used. Six tests of each method of technique were made.

Table 3. Effect of Vaporized Sulfur on Spore Germination.

METHOD OF TECHNIQUE		AVERAGE PERCENT GERMINATION
I.	Dry Spores applied to vaporized sulfur residue	26.1
II.	Dry Spores exposed to vaporized sulfur	26.6
IV.	Spores in water drop applied to vaporized sulfur residue	15.9
V.	Spores in water drop exposed to vaporized sulfur	26 6
VI.	Spores sprayed with water, then exposed to vaporized sulfur	15.1
VII.	Spores sprayed with water after exposure to vaporized sulfur	1.6
Check.	Spores applied dry to clean glass slides	79.1
Check.	Spores applied in water drop to clean glass slides	55 8

This study failed to show that the toxicity of vaporized sulfur is due to its fumes. Varying degrees of control of germination were obtained by all methods of exposure, but instances of total inhibition were obtained only when spores were exposed in water to the vapors (V), or conveyed in water to the residue (IV), or atomized with water (VII) after exposure. It was anticipated that immersion in the sulfur droplets (II) would provide a greater lethal action than when the spores were applied to the dry residue

PLATE I



Microphotographs showing: Relative Physical Properties and Distribution of (A) Sulfur Dust, and (C) Vaporized Sulfur, x 75; (B) Germinating Cladosporium Spores Unaffected by Sulfur Dust, x 225; (D) Effect of Vaporized Sulfur in Preventing Germination of Spores, x 225; and (E) Cladosporium Spores Embedded in Dried Droplets of Vaporized Sulfur, x 300.

(I), but no such differences were consistently noted and the average of the results of the six tests by each of these two methods of exposure was the same. Sulfuric acid was produced only when moisture was present on the slides but in some instances no acid was produced in the presence of moisture, air conditions being practically the same. Acid media below a pH value of 5.7 were consistently toxic to spores, but the toxicity of vaporized sulfur was not due alone to acidity for in some instances complete control of germination occurred in alkaline and neutral media. The production of sulfuric acid did not appear to be influenced by either the exposure or the incubating temperatures, and toxicity was not correlated with any particular temperature.

Barker, Gimingham and Wiltshire (4) offered as one of the reasons for the toxic action of sulfur the irritant character of finely divided particles which stimulate to an injurious extent cells exposed to their action. One would expect a much greater irritant effect from vaporized sulfur in its change from the fluid to the dry state than from dry sulfur powders. The incrustations of sulfur surrounding the spores after drying of the droplets also would appear to interfere with the absorption of moisture necessary for germination (Plate I, E). Kraemer (19, 20) reported that when sulfur was heated very slowly with free access of air almost one-third of the vaporized sulfur was converted into sulfuric acid with very little or no sulfurous acid. On rapid heating and with very little air the proportion of sulfurous acid was increased while the amount of sulfuric acid formed was very much lessened. He asserted that the increased efficiency of vaporized sulfur over flowers or flour sulfur used as a dust is due to the increased proportion of sulfuric acid produced. Numerous workers have attributed the activity of sulfur to sulfuric acid and recognized that sulfuric acid is fungicidal in very weak dilutions, but Barker, Gimingham and Wiltshire (4) and Vogt (35) found that none of the compounds which might possibly be derived from sulfur, among which are mentioned sulfuric and sulfurous acids and sulfur dioxide, could account for its toxic action.

Control of Infection of Potted Plants

Those fungicides considered in the studies on spore toxicity were tested for their value in preventing infection of potted tomato plants. Two plants 8 to 12 inches high were used in each test. The potted plants were placed in a glass chamber 34x22x18 inches in size for the dust treatments. Small Feeney hand dusters were used for applying the dusting materials. The pots were placed in inverted and upright positions in the chamber to obtain coverings of dust on the lower and upper surfaces alike. The same chamber was charged with vaporized sulfur, and potted plants were confined in the charged atmosphere long enough to show a covering of sulfur. Sprays were applied with a quart capacity atomizer and both leaf surfaces were thoroughly wetted. The spray was permitted to dry before the plants were inoculated. The plants were inoculated in two ways: (1) sprayed with a water suspension of spores and (2) dusted with spores.

The water suspension of spores applied after the treatments was allowed to dry previous to incubation. The dry plants were placed in a glass chamber of 175 cu. ft. A saturated atmosphere was obtained and a range of temperatures from 80° to 95° F. prevailed. The fungus was incubated for 24 to 36 hours. The plants were then removed from the pots and planted in the greenhouse. When the disease was evident on the untreated controls, counts of the leaflets were made to determine the relative merits of the fungicides considered. Only foliage present on the plants at the time of the treatments was considered in the counts.

When the fungus was applied in water (Table 4), the stronger Bordeaux mixtures furnished better control than the weaker, and the same was true of copper sulfate sprays. Copper-lime dusts proved efficient. Hammond's Slug Shot gave favorable control. Sulfur dusting materials were of no merit, but vaporized sulfur was effective. Lime-sulfur in 1-50 and 1-100 dilutions gave excellent control but also injury. Semesan .25 per cent was inferior to Uspulun .25 per cent. The difference is apparently due to the filler in Uspulun. When the plants were inoculated with dry spores (Table 4), only vaporized sulfur and Grape Dust gave significant control.

Table 4. Comparative Merits of Fungicides in Preventing Infection of Potted Tomato Plants.

Fungicide	Spores Applied in Water		Spores Applied Dry	
	Leaflets Counted	Leaflets Diseased	Leaflets Counted	Leaflets Diseased
		per cent		*per cent*
Check	100	*57.0*	183	*85.2*
Anchor Brand Sulfur Dust	108	*32.4*		
Grape Dust	100	*19.0*	99	*6.0*
Schloesing's Sulfur	119	*46.2*	141	*55.3*
Hammond's Slug Shot	90	*10.0*	131	*62.5*
Trick Sulfur	83	*22.8*	127	*33.0*
Vaporized Sulfur	93	*4.3*	123	*7.3*
H. & H. Colloidal Sulfur	95	*22.1*	144	*38.1*
Lime-Sulfur .2%	81	*0.0*		
Lime-Sulfur .8%			140	*85.0*
Lime-Sulfur 1.%	79	*7.5*		
Potassium Sulfide .08%			136	*93.3*
Schacht's Naphtal-Schwefel			154	*39.6*
Sulfur-Lime-Naphthalene 1-1-1	94	*35.1*	143	*27.9*
Sulfuric Acid .05%			135	*87.4*
Sulfuric Acid .04%			144	*75.6*
Copper Sulfate .06%	88	*5.6*		
Copper Sulfate .05%	88	*17.0*	150	*77.3*
Copper Sulfate .04%	98	*47.9*	149	*62.4*
Bordeaux 1-1-50	87	*13.6*	83	*91.5*
Bordeaux 4-4-50	95	*5.2*	117	*57.2*
Bordeaux 6-6-50	97	*1.0*		
Copper-Lime Dust 10-90	82	*2.4*	122	*61.4*
Copper-Lime Dust 20-80			124	*40.3*
Copper-Lime Dust 50-50	86	*6.9*		
Niagara D-25 Copper Dust			135	*58.5*
Semesan .25%	101	*16.8*		
Uspulun .25%	106	*4.7*		
Uspulun .1%			137	*81.0*

In a further experiment, plants were dusted in upright and inverted positions. When plants were inoculated with spores in water (Table 5) the best control was obtained with Grape Dust, copper-lime dust, vaporized sulfur, and Uspulun. When they were inoculated with dry spores (Table 5) significant control was obtained only with vaporized sulfur.

Table 5. Comparative Merits of Fungicides in Preventing Infection of Potted Tomato Plants. Both Leaf Surfaces Treated.

FUNGICIDE	SPORES APPLIED IN WATER		SPORES APPLIED DRY	
	Leaflets Counted	Leaflets Diseased	Leaflets Counted	Leaflets Diseased
		per cent		*per cent*
Check	93	*28.5*	117	*67.5*
Grape Dust	117	*5.1*	90	*23.3*
Schloesing's Sulfur	123	*26.8*	82	*17.0*
Vaporized Sulfur	105	*1.9*	60	*1.6*
Solbar 1%	76	*32.8*		
Copper-Lime Dust 20-80	82	*8.5*	110	*42.7*
Uspulun .5%	88	*2.2*	123	*58.6*

In another test Bordeaux 4-4-50, Solbar 1 per cent and Uspulun .5 per cent offered a high degree of control when the treated plants were inoculated with spores in water (Table 6). When spores were applied dry, only Solbar offered effective control.

Table 6. Comparative Merits of Fungicides in Preventing Infection of Potted Tomato Plants.

FUNGICIDE	SPORES APPLIED IN WATER		SPORES APPLIED DRY	
	Leaflets Counted	Leaflets Diseased	Leaflets Counted	Leaflets Diseased
		per cent		*per cent*
Check	122	*55.7*	211	*85.3*
Potassium Sulfide .4%	123	*21.1*	108	*82.4*
Solbar 1%	126	*6.6*	129	*9.3*
Copper Sulfate .05%			188	*78.1*
Bordeaux 4-4-50	129	*0.7*	146	*19.8*
Uspulun .5%	154	*7.7*	197	*17.7*

The materials which controlled infection on as much as 85 per cent of the foliage in these experiments are listed in Table 7. When water was used as a carrier for the inoculum, consistent favorable controls were obtained with Bordeaux, copper-lime dust, vaporized sulfur, and Uspulun; while copper sulfate, Slug Shot and lime-sulfur gave favorable control in the single test made. Solbar and Grape Dust were effective in one test and not in another, while Semesan permitted 16.8 per cent of the foliage to become infected against 4.7 per cent with Uspulun. All other fungicides tested were not effective. When spores were applied dry, only vaporized sulfur gave consistent control. Solbar gave favorable control in the single test in which it was tried, and Grape Dust was effective in one test and not in another. All other materials failed to offer satisfactory control. The poor control indicated by Semesan as compared with Uspulun and by Grape Dust (spores applied dry) were in reality significant controls although less than 85 per cent, the percentage on which Table 7 is based.

It is significant that when both leaf surfaces were covered with vaporized

Table 7. Summary of Control of Infection of Potted Tomato Plants with Fungicides.

	Spores Applied in Water			Spores Applied Dry		
	Times Tested	Times Control Favorable	Times Control Unfavorable	Times Tested	Times Control Favorable	Times Control Unfavorable
Grape Dust	2	1	1	2	1	1
Hammond's Slug Shot	1	1	0			
Vaporized Sulfur	2	2	0	2	2	0
Lime-Sulfur	1	1	0			
Solbar	2	1	1	1	1	0
Copper Sulfate	1	1	0			
Bordeaux mixture	2	2	0			
Copper-Lime Dust	2	2	0			
Semesan	1	0	1			
Uspulun	3	3	0	3	0	3

sulfur, superior and more uniform results were obtained than when the upper leaf surfaces only were protected. In general this was also true of other materials such as Uspulun, copper fungicides, etc., excepting sulfur, when plants were inoculated with a suspension of spores in water. This is explained at least in part by the fact that leaf infection is almost altogether hypophyllous. However, when plants treated in this manner were inoculated with dry spores, vaporized sulfur showed a marked effect, and Grape Dust a somewhat inferior effect.

The use of spraying and dusting materials in general is not applicable to greenhouse tomato culture, one reason being the undesirable effect of the fungicide upon the plant. Bordeaux mixture leaves a residue. Lime-sulfur is injurious and leaves a residue and sulfur odor. Uspulun is toxic to the foliage at .25 per cent strength, and both Semesan and Uspulun impart a phenol flavor to the tomato fruit. This fact has already been recognized by Triebels (33), Lüstner (21) and Jaenicke (17). Solbar leaves a heavy residue and sulfur-lime-naphthalene dust imparts a naphthalene flavor to the fruit. Vaporized sulfur and Grape Dust are desirable, but the results suggest that vaporized sulfur would offer the most satisfactory control under the conditions prevailing in tomato houses.

Data in Tables 1 and 7 show that materials toxic to the spores in laboratory tests gave the most satisfactory control of infection with few exceptions. Those showing this effect when the fungus was applied in water were copper materials, organic mercury compounds, vaporized sulfur, Slug Shot and Grape Dust. In the absence of water, vaporized sulfur gave the same effect, while Solbar, Uspulun, and Grape Dust did not. No control was anticipated with sulfur dusting materials, but potassium sulfide was expected to show some control of foliage infection and did not. Sulfuric acid proved of no value and Schacht's Naphtal-Schwefel, which was the most effective of all dusting materials considered, failed to give control in a single trial.

The remarkable control of foliage infection of potted plants with vaporized sulfur in contrast to the inconsistent control of spore germination in laboratory slide tests indicates that conditions existing on foliage are much more favorable for toxicity of vaporized sulfur than on slides in Petri dishes. Under greenhouse cultural conditions tomato foliage is usually bathed in thin invisible films of transpired moisture, the amount of which is increased with high temperatures. Inferring from the results (Table 3, VI, VII) which are outstanding, this film of moisture provides suitable conditions for toxicity. The results show that protection from infection may be obtained by the presence on the leaves of a covering of vaporized sulfur, and that destruction of exposed sources of the fungus in greenhouses may be realized by vaporizing sulfur at frequent intervals.

COMMERCIAL CONTROL

Spraying and Dusting Materials

In the spring of 1925, at the Market Garden Field Station in Waltham, plats of tomatoes were treated with commercial liquid lime-sulfur 2 per cent, Bordeaux mixture 4-4-50, sulfur dust, copper sulfate-resin fish oil soap (½ pound of copper sulfate, 5 pounds of resin fish oil soap, 50 gallons of water), copper-lime dust 20-80, potassium sulfide and flour paste (5 pounds flour, 4 pounds potassium sulfide, 100 gallons water), ammoniacal copper carbonate of the usual formula, and New Jersey Dry Mix. The treatments were begun at the first appearance of the disease and continued at seven to ten-day intervals. No control was obtained. The disease was as prevalent in the treated plats as in the check. Lime-sulfur proved injurious to the foliage.

It might be assumed from the above that lack of control was due to the lateness of the initial treatments and the absence of early protection from infection. To eliminate any doubt of the ineffectiveness of copper and sulfur sprays and dusts under greenhouse conditions which the above experiment might offer, a further experiment was conducted in the fall of 1925. The treatments were started shortly after the plants were set and continued at weekly intervals. The plants were grown outdoors and set in the greenhouse September 25. The following materials were applied: Bordeaux 3-4-50, copper-lime dust 19-81, New Jersey Dry Mix, sulfur-lime dust 75-25, and Burgundy mixture. A total of eleven applications was made, the first on September 28 and the last on January 6. No control was obtained.

In the fall of 1926 at the Frank Wheeler Estate, Concord, Mass., individual houses were dusted at weekly intervals beginning five days after the plants were set, with Grape Dust, copper-lime dust 20-80, Schloesing's sulfur and Trick sulfur. The dusting was done from between the rows while all the ventilators were closed. Feeney Model-D two-quart dusters with up-turned nozzles were used, and every effort was made to get coverings of dust on the lower leaf surfaces. Five to six pounds of dust were applied each week. The treatments were discontinued after five applications had been made because no control was obtained.

In the fall of 1927 a control experiment was conducted at the Market Garden Field Station in which selected sprays were compared for their effect on the disease. Individual rows were 25 feet long and 3 feet apart. The plants were set July 31. Foliage on both upper and lower sides was as thoroughly wetted with spray as was practically possible. The first treatments were made August 10, and later treatments on August 17, 27, September 2, 9, 19, 28, October 10 and 25, making a total of nine treatments. The vines were topped to the wires on October 25, preceding the last treatment. All of the foliage was covered with fungicide and all of it present at each application was wetted with spray. After August 27 ventilation was purposely neglected to provide favorable conditions for the development of the fungus. The ventilators were closed at night and heat was not used until November 1. Foliage counts of the prunings were made at intervals during the growth of the crop. The materials used and the tabulated control results are presented in Table 8. As the counts show, none of the materials, except possibly Solbar and Uspulun, was effective. The disease became so serious that no leaves free of Cladosporium were found on the later counts in any of the plats. Solbar and Uspulun furnished the better controls early in the growth of the crop but these were so slight as to have no effect upon the yield or later incidence of the disease. All materials excepting Solbar caused injury; Solbar and lime-sulfur left residues on the fruit; and Uspulun, lime-sulfur and potassium sulfide left an objectionable flavor.

A control experiment with spraying materials was conducted in one of the greenhouses of J. Winthrop Stone in Watertown, Mass. Single rows across the width of the greenhouse were treated with liquid materials selected to offer the best control. The plants were set during the first week in September. Treatments were made on October 7, 17 and 31. There was no leaf-mold present when the first treatments were made. On the first application Uspulun was used at .25 per cent strength and caused burning. In subsequent treatments its strength was reduced to .20 per cent. New Jersey Dry Mix 1.25 per cent was substituted for sulfuric acid .03 per cent in the second treatment on account of injury resulting from the latter. Uspulun, copper sulfate, potassium sulfide, lime-sulfur and New Jersey Dry Mix were injurious to the foliage,—the sulfur materials especially so on the sunny side of the rows. Bordeaux mixture, lime-sulfur, New Jersey Dry Mix and Solbar left heavy residues. Foliage counts were made on November 21, December 14 and January 1 (Table 9). Only treated foliage was considered in the counts, except in the count of January 1 when some of the slightly treated and untreated leaves were included with the prunings. This foliage represented the upper rosette of leaves when the final application of October 31 was made and since the leaves were rather small and sheltered at that time coverings of spray were not as good as on the older and more fully developed leaves represented in the counts previous to January 1. The perceptible residues from Bordeaux, Solbar, lime-sulfur and New Jersey Dry Mix permitted discarding any foliage not showing residue, but since Uspulun, Semesan, potassium sulfide and copper sulfate left no discernible residues no segregation of covered and uncovered leaves was possible. It appears for this reason that the controls of January 1 do not coincide with those previously obtained.

On this crop, heating was practiced liberally from the time the plants were set. Three lines of heating pipe each 12 feet apart extended lengthwise through the greenhouse above the ground in addition to the piping along the side walls. Since it was evident on October 31 when the final treatments were made that liberal heating was controlling the disease effectively, further treatments were discontinued. Infection, therefore, was not severe enough so that the relative efficiency of the materials used could be determined by casual observation. Foliage counts, however, showed a superior effect from Uspulun and Solbar, but the significance of these counts is decreased considerably by the relative lack of disease in the controls.

Spore toxicity studies showed that naphthalene is fungicidal to the spores of Cladosporium and suggest that the frequent disinfection of the tomato vines with naphthalene dust should offer control. This material was considered regardless of the effect its vapors have upon the quality of the fruit. A compartment of the greenhouse with a bed area of 900 square feet and a volume of 10,000 cubic feet was used. The tomatoes were set early in February, 1926. A sulfur-lime-naphthalene dust containing one part of each ingredient was used. Nine treatments were made during the interval February 23 to May 13. The disease was observed April 12 and from then on became increasingly prevalent. As early as May it was observed that control was not being obtained and in consequence of that fact treatments were discontinued after May 13. The disease assumed epidemic development, and leaf counts were not considered necessary to demonstrate this fact.

The work has demonstrated that because of the manner of infection of the

Table 8. Control of Tomato Leaf-Mold with Fungicides. Market GardenField Station, Waltham. Fall Crop 1927.

FUNGICIDES	SEPTEMBER 1		SEPTEMBER 13		OCTOBER 10		OCTOBER 31		DECEMBER 1		TOTALS	
	Leaflets Counted	Leaflets Diseased	Leaflets Counted	Leaflets Diseased	Leaflets Counted	Leaflets Diseased	Leaflets Counted	Leaflets Diseased	Leaflets Counted	Leaflets Diseased	Leaflets Counted	Leaflets Diseased
		per cent		*per cent*		*per cent*		*per cent*		*per cent*		*per cent*
Lime-Sulfur 1%	140	*.7*	202	*4.9*	236	*52.5*	430	*100*	389	*100*	1397	*68.2*
Sulfuric Acid .04%	151	*4.6*	248	*12.0*	203	*98.5*	433	*100*	410	*100*	1445	*74.7*
Uspulun .25%	156	*1.2*	254	*0.3*	302	*23.8*	382	*100*	421	*100*	1515	*57.9*
Copper Sulfate .03%	106	*.0*	120	*0.8*	218	*88.0*	417	*100*	331	*100*	1292	*78.9*
Potassium Sulfide .4%	126	*.0*	131	*9.1*	258	*64.3*	481	*100*	342	*100*	1338	*74.8*
Solbar 1%	265	*1.1*	283	*2.8*	265	*54.3*	392	*100*	370	*100*	1575	*58.2*
Check	310	*9.3*	316	*63.2*	185	*98.8*	401	*100*	400	*100*	1612	*74.6*

Table 9. Control of Tomato Leaf-Mold with Fungicides. Watertown. Fall Crop 1927.

FUNGICIDES	NOVEMBER 21		DECEMBER 14		JANUARY 1		TOTALS	
	Leaflets Counted	Leaflets Diseased	Leaflets Counted	Leaflets Diseased	Leaflets Counted	Leaflets Diseased	Leaflets Counted	Leaflets Diseased
		per cent		*per cent*		*per cent*		*per cent*
Bordeaux 4-4-50	454	*7.4*	447	*1.8*	307	*.9*	1208	*3.8*
Semesan .25%	517	*8.4*	372	*2.9*	262	*5.3*	1151	*5.9*
Uspulun .20%	347	*3.4*	452	*.8*	335	*3.8*	1134	*2.5*
Copper Sulfate .04%	509	*6.0*	451	*2.4*	229	*4.8*	1189	*4.4*
Potassium Sulfide .3%	404	*5.1*	324	*6.1*	213	*4.2*	941	*5.3*
Solbar 1%	492	*2.8*	363	*1.3*	223	*1.3*	1078	*2.0*
Lime-Sulfur 1%	351	*5.7*	352	*2.5*	339	*2.9*	1042	*3.7*
New Jersey Dry Mix 1.25%	306	*5.5*	293	*2.4*	209	*9.0*	808	*5.3*
Check	593	*.7*	642	*7.3*	576	*4.1*	1811	*6.4*

foliage and atmospheric conditions under glass, the fungus does not readily lend itself to control with spraying and much less with dusting materials. Spraying is not practicable. A dusting material like naphthalene having an aseptic volatile principle is most promising, but this study has not revealed any materials of such a nature that are effective when applied under commercial conditions of culture. Past recommendations appear to have been based on observational evidence which is misleading. The effect of the fungicide upon the appearance and flavor of the fruit and the health of the foliage, and the practicability of applying fungicidal materials in a manner to promise control were disregarded.

Fumigants

Control of spore germination with naphthalene vapors in Petri dish tests offered encouragement for tests in larger volumes of atmosphere. In a compartment of the greenhouse of a volume of 5,000 cubic feet, 5 pounds of pure naphthalene flakes were vaporized, by the method described by Hartzell (11), from 12 o'clock noon of March 21 to 7 a. m. of the following day. Slides bearing dry spores of Cladosporium were exposed to the treated atmosphere. After fumigation was completed the slides were removed to moist Petri dishes. Normal germination of spores occurred. Naphthalene did not prove effective under the conditions of the experiment. In another trial the same quantity of naphthalene was vaporized and the same method of exposing spores was followed, but the effect was negative. In both tests the maximum quantity of naphthalene per unit volume considered safe to foliage was used. The air temperature during the operation was above 80° F. and the relative humidity close to the saturation point. High temperatures were necessary to prevent condensation of naphthalene on the foliage and injury resulting therefrom. The treatments imparted a strong odor of naphthalene to the tomatoes. For this reason neither the vapors nor the dust are applicable to tomato culture. Parker (28) and Speyer (31, 32) claim that tainting is imparted only to ripe fruit and that the naphthalene flavor leaves the fruit within twenty-four hours after picking, when it is exposed to fresh air. Fruit from tomato houses treated with naphthalene materials was unsalable.

The vapors from a .4 per cent solution of formaldehyde (1-100) are lethal to the spores of Cladosporium (Table 1). A 1-400 mixture is lethal but its vapors are not. Soil disinfection of the greenhouse with formaldehyde 1-100 following which the house was closed tight for 24 hours produced an atmosphere lethal to Cladosporium spores. However, the sterilization of the houses with formaldehyde has not at any time offered any measure of control of the disease on the subsequent crop. The fungus exists in the field and frequently is very prevalent on field tomatoes in Massachusetts. This outside source of the fungus precludes the possibility of obtaining much benefit from soil sterilization and fumigation of the greenhouse with formaldehyde.

Sulfur dusting and spraying materials have not given control. The volatile principle of sulfur (Table 1, V) is not toxic and dusting sulfur in contact with dry spores does not prevent germination. Sulfur dioxide obtained by burning sulfur is lethal and is an excellent fumigant for this purpose. In a single experiment 1¼ pounds of sulfur were burned in a compartment of a volume of 5000 cubic feet, in which were growing tomato vines badly infected with leaf-mold. The time consumed for fumigating was five hours. Slides bearing dry Cladosporium spores were distributed in the greenhouse. After fumigation, reaction tests were made of the foliage, wood, metal and glass surfaces. Acidity was strong even in sheltered portions of leaves covered with the leaf-mold fungus. Spores on glass slides exposed to the fumigant were killed, and twelve mounts of spores obtained from the treated vines gave no germination. Qualitative tests of the mold on the leaves gave strongly acid reactions. Spores collected previous to fumigation germinated excellently. The fumes of burning sulfur are extremely lethal and penetrating. The practice of burning sulfur before planting tomatoes is an economical and effective means of destroying the fungus and safeguarding the future crop from an inside potential source of attack.

Vaporized Sulfur

Methods of Vaporizing.

Sulfur on heating pipes. The practice of treating the heating pipes with sulfur powders, pastes and liquids prevails among growers of greenhouse plants. It is considered a practical means of controlling certain fungous diseases but has its limitations. In California, because of its mild climate, steam pipe surface in greenhouses is small and very little heat is used, as a result of which the sulfur treatment of the pipes cannot be relied upon to control cucumber powdery mildew, according to Milbrath (25). In Massachusetts, varying results have been obtained in proportion to the area of pipe surface treated and the temperature of the pipes. The value of the practice is very much in dispute among commercial growers. Observations in tomato houses where the practice has been rigidly followed for controlling leaf-mold indicate that it is of doubtful value. According to Parker (27) and Höstermann (14) the sulfur treatment of the heating pipes is not safe at high pipe temperatures. The danger lies in the production of sulfur dioxide, sulfurous and sulfuric acid in sufficient volumes to cause injury to the growing plants. These sulfur oxidation products also have a corrosive action on the pipes, and the scale which forms interferes with the radiation of heat. Pipes treated repeatedly are not considered lasting, and some growers dislike engaging in the practice for that reason. For practical reasons the sulfuring of heating pipes is restricted to the colder months when heat is used. Since the conditions which favor the development of tomato leaf-mold to the extent of causing yield reduction appear usually between the latter part of May and the middle of November, in Massachusetts, when little or no heating is practiced, the use of special heating units for vaporizing sulfur would be extremely economical and desirable.

Mechanical sulfur vaporizers. The vaporization of sulfur with oil stoves has been recommended by Bailey (3), Humphrey (15, 16), Norton and White (26), Maynard (24) and others for controlling powdery mildews. The apparatus suggested was never received with favor by growers of greenhouse plants in spite of the effectiveness of the practice. The oil stoves were not adaptable for operation in large houses, and in small houses where effective results could be realized ignition of the sulfur occurred frequently. The small quantity of sulfur discharged, often giving unsatisfactory control, the danger of its ignition, the necessity of keeping constant watch of the apparatus, and the lack of adaptation of such apparatus to commercial establishments led to its disfavor. More recently Campbell's Patent Sulfur Vaporizer has been used to a limited extent. In the construction of this apparatus provision was made to exclude the oxygen of the air while vaporization is in progress, the purpose being to prevent ignition of the sulfur which, however, it fails to do. Its operation is extremely dangerous to plant life and unpractical for commercial purposes.

Rupprecht (29) and Vogt (34) reported a portable apparatus, the Rota-Generator, so constructed as to prevent the oxidation of sulfur by generating non-oxidized sulfur vapors under the exclusion of air mixed with steam entering under pressure. The sulfur vapors which otherwise would issue slowly are forced out rapidly by steam blasts. The merits claimed for the device are safety of operation, rapid production of vapors, and the extreme fineness of the sulfur. According to Vogt (36) the expectations which some thought were to be realized by this invention have not materialized. It is adapted only to greenhouses, and here its practical value is questionable since interruptions occur in its operation because of mechanical complications in construction.

Improved sulfur vaporizers. The lack of adaptation or acceptance of the patented types of vaporizers led to the study of equipment suitable and practical for use in greenhouses in Massachusetts.

In Massachusetts, electricity is employed for lighting purposes in practically all greenhouse establishments although only the boiler and packing rooms are wired. The writer conceived the idea of vaporizing sulfur in porcelain evaporating dishes on electric hot plates. The flat heating surface of the hot plate was covered with a square of ¼ inch asbestos board with a hole 4½ inches in diameter in which was set a round-bottom porcelain evaporating dish (Plate II A). Two heavy copper insulated wires of No. 6 gauge were installed along the entire length of the greenhouse. At frequent points on the wires electric sockets were connected, into which the hot plates were plugged (Plate II B and C). With a sufficient source of electric current, houses of any capacity may be treated with vaporized sulfur in this manner. Where several large houses comprise the range a power line connected with each house would appear to be most satisfactory. On the other hand, in a range with houses 200 x 30 feet, and with a 25 ampere meter and No. 30 fuses, the lighting circuit should offer sufficient electric current. In any event a strong current is necessary to produce the heat required for vigorous fuming of the sulfur.

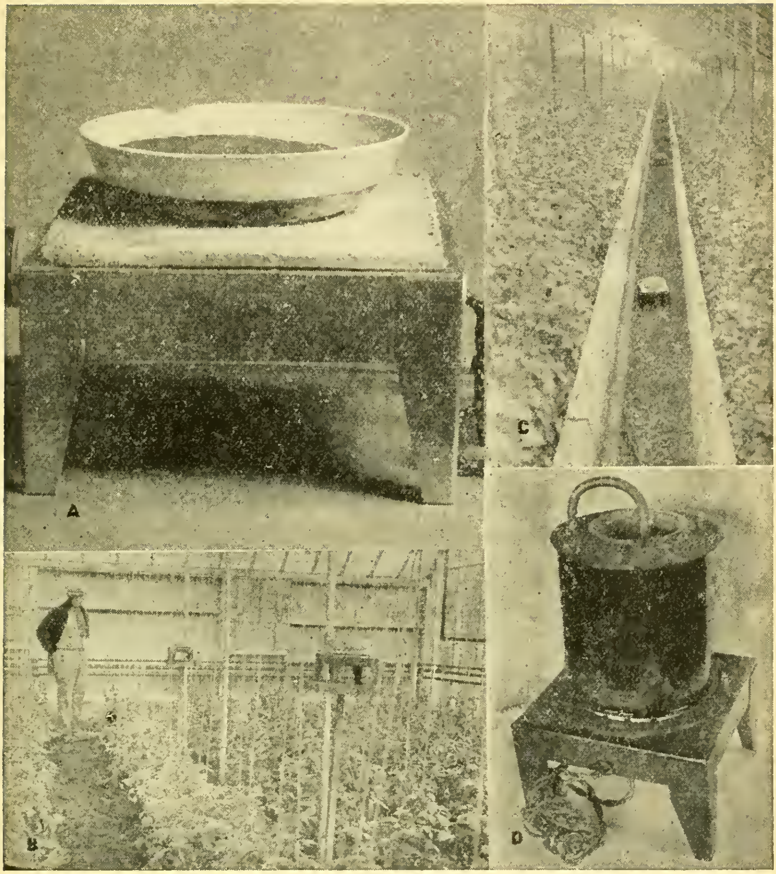
The cost of the heating equipment is small. The electric plates retail for $1.00 each, and evaporating dishes 185 mm. in diameter, 50 mm. deep and 765 ml. capacity, for $1.08. The price of ¼ inch asbestos board is $0.20 per pound. The total cost of each unit excluding wires and socket fixtures is about $2.15. When operated on a power line the cost of operation is much less than if on a lighting circuit. The economy and convenience of this method of controlling Cladosporium leaf-mold is appealing.

A sulfur vaporizer designed by the writer and embodying the principle involved in the Rota-Generator but simpler of construction has been used (Plate II D). Water is contained in a cylindrical copper tank, the center of which is provided with a sulfur receptacle of heavy Pyrex glass. Both water and sulfur are heated by an electric hot plate and the steam generated is blasted into the molten sulfur through a metal tube. The sulfur vapors are discharged much more rapidly than with the other apparatus described. The glass sulfur receptacle is undesirable and the metal steam conductor is acted upon by molten sulfur. If these objectionable mechanical features can be overcome this apparatus would prove highly satisfactory for commercial purposes.

Greenhouse Tests.

A series of control experiments were instituted at the Market Garden Field Station greenhouse at Waltham and at the range of Wm. H. Derby, Melrose,

PLATE II



(A) Electric Hot Plate with Asbestos Mat and Evaporating Dish Assembled for Vaporizing Sulfur; (B) Vaporizing Equipment in Operation in Tomato Greenhouse, and (C) in Rose Greenhouse; (D) Sulfur Vaporizer Constructed to Provide Addition of Steam Blasts to Molten Sulfur.

Mass. At Melrose, No. 1 house has a volume of 10,980, No. 2, 37,800, and No. 3, 68,800 cubic feet. At Waltham, No. 7 house has a volume of 10,000, and No. 3, 5,000 cubic feet. Sulfur was vaporized on electric heating units by the method described. The work was done in the evening and all the ventilators were closed for the night to confine the vapors and permit them to settle naturally. The heating units were operated for two to four hours at a time and disconnected when the vapors in the air were quite dense. Counts were made of the leaf prunings to determine the degree of control, and on the last count the plants were stripped of the remaining leaves. This method proved most satisfactory for ascertaining the value of the treatment.

Spring Crop at Melrose, 1926. Sulfur was vaporized 16 times with 5 stoves at weekly intervals beginning March 2 and ending July 4. The greenhouses were cleaned out July 31. The results of the experiment are shown in Table 10. Both houses in the experiment were subjected to the same conditions.

Table 10.—Control of Tomato Leaf-Mold with Vaporized Sulfur. Melrose. Spring Crop 1926.

Date	Sulfured House No. 2		Check House No. 3	
	Leaflets Counted	Leaflets Diseased	Leaflets Counted	Leaflets Diseased
		per cent		*per cent*
June 2	795	*0.2*	1117	*28.0*
June 29	1207	*0.7*	1540	*55.1*
July 29	2009	*10.8*	1767	*87.4*
Total	**4011**	**5.7**	**4424**	**61.2**

Fall Crop at Melrose, 1926. Three houses of tomatoes were used. The plants were potted July 17 to 20 and treated with vaporized sulfur in the plant house on August 6, using three stoves. The check plants received this single treatment. The houses were set August 20 to 21. Heat was turned on October 1. Seven stoves were used in No. 3 house and six in No. 2 house. Sulfur was vaporized nine times in No. 3 house, the first on August 31 and the last on October 18; and eight times in No. 2 house, the first on September 1 and the last on October 19. The houses were cleaned out January 30 to 31. The results are presented in Table 11.

Table 11.—Control of Tomato Leaf-Mold with Vaporized Sulfur. Melrose. Fall Crop 1926.

Date	Check House No. 1		Sulfured House No. 2		Sulfured House No. 3	
	Leaflets Counted	Leaflets Diseased	Leaflets Counted	Leaflets Diseased	Leaflets Counted	Leaflets Diseased
		per cent		*per cent*		*per cent*
November 1	692	*13.8*	985	*3.9*	1256	*3.4*
December 8	1339	*49.2*	893	*8.5*	1467	*3.6*
December 27	833	*57.6*	1441	*10.6*	1609	*5.1*
January 25	730	*59.3*	1088	*17.4*	734	*14.9*
Total	**3594**	**46.3**	**4407**	**10.4**	**5066**	**5.7**

Fall Crop at Waltham, 1926. Two compartments of the greenhouse were used. The plants were set August 19 to 20, fifteen inches apart in single rows 30 inches apart. Eight times at weekly intervals from August 23 to October 11 sulfur was vaporized with one stove for periods varying from 60 to 90 minutes (connection to disconnection of electricity). The compartments were cleaned out February 1, 1927 (Table 12).

Table 12. Control of Tomato Leaf-Mold with Vaporized Sulfur. Waltham. Fall Crop 1926.

DATE	SULFURED HOUSE NO. 3		CHECK HOUSE NO. 7	
	Leaflets Counted	Leaflets Diseased	Leaflets Counted	Leaflets Diseased
		per cent		*per cent*
September 20	529	*5.2*	396	*9.5*
October 1	585	*1.5*	1368	*2.4*
October 10	553	*0.7*	2259	*23.1*
December 20	428	*17.5*	1096	*75.1*
January 11	1130	*4.6*	1433	*56.3*
January 29	1027	*5.7*	1081	*27.1*
Total	**4252**	**5.3**	**7633**	**33.0**

Spring Crop at Melrose 1927. Three houses were employed in the experiment, two of which were treated with vaporized sulfur (Table 13). The houses were set in the middle of February. Six stoves were used in No. 2 house and eight in No. 3 house. The stoves were operated sixteen times in No. 2 house beginning March 2 and ending June 24; and fifteen times in No. 3 house beginning March 7 and ending June 30. At these intervals electricity was used for periods of one to two and one-half hours, a total of 24½ hours for No. 2 house and 26¾ hours for No. 3 house for the season. All three houses were grown under the same conditions. The houses were cleaned out the last week of July.

Table 13. Control of Tomato Leaf-Mold with Vaporized Sulfur. Melrose. Spring Crop 1927.

DATE	CHECK HOUSE NO. 1		SULFURED HOUSE NO. 2		SULFURED HOUSE NO. 3	
	Leaflets Counted	Leaflets Diseased	Leaflets Counted	Leaflets Diseased	Leaflets Counted	Leaflets Diseased
		per cent		*per cent*		*per cent*
June 16	985	*6.09*	1227	*.08*	1174	*.08*
July 6	481	*41.99*	540	*.00*	701	*.14*
July 19	816	*98.52*	726	*.00*	1146	*.00*
Total	**2282**	**46.71**	**2493**	**.04**	**3021**	**.06**

Fall Crop at Melrose 1927. Four houses were treated with vaporized sulfur and one house was left untreated. No leaf counts were made, but frequent observations during the growth of the vines showed that vaporized sulfur furnished almost perfect control of infection. Leaf-mold was hard to find. In the untreated greenhouse the disease was epidemic and as a result the yield was poor and of second grade.

Recommendations

The conditions predisposing to epidemics of leaf-mold occur between May and November in Massachusetts, which obviates the necessity of particular recommendations for each crop. The spring crop is less affected than the fall crop. This crop should run from February to July, inclusive, and since most of the damage occurs late in June and in July the loss is usually small. The spring crop is started in the cold season of the year when continuous heating is required and does not encounter conditions favorable for the development of leaf-mold until the sun's rays become stronger and heating is discontinued. The fall crop is started early in August. During the first two months the sun's rays are intense, the nights are damp, and no heat is used. The plants are exposed to the danger of epidemic infection up to the time winter weather appears, or usually until about the middle of November, when continuous heating is required. For this reason the fall crop suffers heavily from leaf-mold, often to the extent of shortening the picking season by 1½ to 2 months. Consequently, sulfur should be vaporized in the plant house to guard against infection of the young potted plants.

Immediately following the setting of the houses a further treatment should be made and then repeated at weekly intervals as long as steady heating is not necessary. The foliage infection counts on the spring crops, and observations on the first appearance of the disease suggest that treatments previous to April are not necessary in Massachusetts. The steady use of heat at night and the mild house temperatures during the day up to this time may be relied upon to keep the disease under control.

The simple operation of vaporizing sulfur by the method advocated in this paper offers a practical and efficient means of combating fungous diseases in greenhouses. The striking control of Cladosporium leaf-mold, otherwise only possible by consistent management of air conditions and the liberal use of heat, suggest remarkable possibilities of the adaptation of this method to the control of other fungous parasites of greenhouse plants.

SUMMARY

Sulfur suspensions in water and dusting materials are not fungicidal to germinating spores of *Cladosporium fulvum.* Lime-sulfur and potassium sulfide at high concentrations and temperatures show some merit. Copper fungicides are toxic in the presence of moisture. Lime is not fungicidal. Schacht's Naphtal-Schwefel, naphthalene preparations, Uspulun and Semesan are fungicidal. Formaldehyde, the oxidation products of burning sulfur, and naphthalene are toxic fumigants. Hammond's Slug Shot and Hammond's Grape Dust, each containing a small percentage of copper sulfate, have a slight fungicidal effect in the water drop. Sulfuric acid is toxic at extremely low concentrations by all methods of study, and copper sulfate similarly at stronger concentrations. Vaporized sulfur is toxic, but greatest effect is shown in the presence of moisture.

Control of infection of potted plants inoculated with spores in water was best with copper fungicides, organic mercury, and vaporized sulfur. Lime-sulfur and Hammond's Slug Shot, tested but once, gave favorable control. When the plants were dusted with spores, only vaporized sulfur gave consistent control, while Solbar in a single test gave favorable control.

Only vaporized sulfur has given control of the disease under commercial conditions of tomato culture. Uspulun and Solbar sprays showed some fungicidal value.

The use of spraying or dusting materials under greenhouse conditions is not practical or effective because of (1) The objectionable flavor imparted to fruit, (2) Objectionable residue on fruit, (3) Toxicity to the foliage, (4) Difficulty of covering surfaces which become infected, (5) Lack of conditions necessary to obtain toxicity, and (6) The need of frequent treatments to maintain protection and disinfection.

The expense of firing for the purpose of vaporizing sulfur on the steam pipes on the fall tomato crop is prohibitive. During the heating season the vaporization of sulfur on the pipes may be practiced, but the value of this method for controlling leaf-mold is doubtful. In the absence of pipe heat conditions prevail which favor epidemics of leaf-mold. Electrical equipment for vaporizing sulfur on a commercial scale provides a very economical, practical and effective method of controlling tomato leaf-mold in the greenhouse. The practice offers possibilities of dealing effectively with foliage diseases of greenhouse plants, and is considered a great improvement over existing methods of dusting and spraying.

LITERATURE CITED

1. Anonymous. De Bladvlekkenziekte der Tomaten. Floralia 48:363-364, 1927.
2. Baehr, ——. Die Tomatenfleckenkrankheit, *Cladosporium fulvum*. Möllers Deut. Gärt. Ztg. 38:204, 1923.
3. Bailey, L. H. The forcing of English cucumbers. N. Y. (Cornell) Agr. Expt. Sta. Bul. 31:123-139, 1891.
4. Barker, B. T. P., Gimingham, C. T. and Wiltshire, S. P. Sulfur as a fungicide. Univ. Bristol, Agr. and Hort. Research Sta. Ann. Rpt. (1919):57-75, 1920.
5. ————, and Wallace, T. A new method of sulfur fumigation. Univ. Bristol, Agr. and Hort. Research Sta. Ann. Rpt. (1921):122-124, 1922.
6. Bewley, W. F. Diseases of glasshouse plants. 208 p. London, 1923.
7. D., A. M. Flojlsplet. Gartner-Tidende 43:41-45, 1927.
8. Dyke, W. The A. B. C. of tomato culture under glass. 165 p. London, 1925.
9. Edgerton, G. W. Delayed ripening of tomatoes caused by spraying with Bordeaux mixture. Phytopathology 8:69, 1918. (Abstract.)
10. ———— and Moreland, C. C. Diseases of tomatoes in Louisiana. La. Agr. Expt. Sta. Bul. 142, 23 p., 1913.
11. Hartzell, A. Naphthalene fumigation of greenhouses. Jour. Econ. Ent. 19:13-19, 1926. Reprinted as Boyce Thompson Inst. for Plant Research Prof. Paper 3:13-19, 1926.
12. Hasper, E. Biologie und Bekampfung des *Cladosporium fulvum* Cke. auf *Solanum lycopersicum*. Ztschr. Pflanzenkrank. 35:112-118, 1925.
13. Hofferichter, K. Eine verheerende Tomatenkrankheit. Gartenflora 73: 60-61, 1924.
14. Höstermann, G. Eine bedenklicke Art der Verwendung von Schwefel als Pflanzenschutzmittel. Gartenwelt 28:183-184, 1924.
15. Humphrey, J. E. The powdery mildew of the cucumber,—*Erysiphe cichoracearum* DC. Mass. State Agr. Expt. Sta. Ann. Rpt. (1891) 9:222-226, 1892.
16. ———— Treatment for powdery mildews. Mass. State. Agr. Expt. Sta. Ann. Rpt. (1892) 10:243-245, 1893.

17. Jaenicke, A. Einiges über Tomatenkrankheiten unter Glas im Jahre 1927. Obst. und Gemüsebau 73:261-263, 1927.

18. Jonassen, E. Tomatenkrankheit, *Cladosporium fulvum*. Möllers Deut. Gärt. Ztg. 38:276, 1923.

19. Kraemer, H. Dilute sulfuric acid as a fungicide. Amer. Phil. Soc. Proc. 45:157-163, 1906.

20. ———— Use of dilute solutions of sulfuric acid as a fungicide. Science n. ser. 23:911, 1906.

21. Lüstner, G. Der Tomatenkrebs. Obst. und Gemüsebau 73:166-167, 1927.

22. Makemson, W. K. The leaf mold of tomatoes caused by *Cladosporium fulvum* Cke. Mich. Acad. Sci. Ann. Rpt. (1918) 20:311-348, 1919.

23. Massey, W. F. and Rhodes, A. Gardening under glass. N. C. Agr. Expt. Sta. Bul. 170, 24 p., 1900.

24. Maynard, S. T. Experiments in heating greenhouses. Mass. (Hatch) Agr. Expt. Sta. Bul. 4:1-22, 1889.

25. Milbrath, D. G. Control of diseases of cucumbers in greenhouses. Calif. Dept. Agr. Mo. Bul. 11:430-437, 1922.

26. Norton, J. B. S. and White, T. H. Rose mildew. Md. Agr. Expt. Sta. Bul. 156:73-80, 1911.

27. Parker, T. The suppression of insect pests and fungoid diseases. 4. Control of certain fungoid diseases. Bur. Bio-Technol., Leeds, Bul. 2: No. 10:68-72, 1923.

28. ———— The control of red spider. Hort. Trade Jour. 29: No. 39: 27-28, 1925; No. 40:27-28, 1925.

29. Rupprecht, G. Ein neues Verfahren zum Schwefeln von Pflanzenkulturen. Angew. Bot. 3:253-262, 1921.

30. Sherbakoff, C. D. Tomato diseases. Fla. Agr. Expt. Sta. Bul. 146:117-132, 1918.

31. Speyer, E. R. The use of naphthalene as a fumigant in control of red spider and other pests in cucumber houses. Nature [London] 114: No. 2858:193, 1924.

32. ———— Entomological investigations. Expt. and Research Sta., Cheshunt, Herts, Ann. Rpt. (1924) 10:82-104, 1925.

33. Triebels, H. Die Bekampfung der Braunfleckenkrankheit bei Tomaten. Gartenwelt 31:368-370, 1927.

34. Vogt, E. Ein neuer Schwefelapparat. Nachrichtenbl. f. d. deut. Pflanzenschutzdienst 1:4:29, 1921.

35. ———— Untersuchungen über den Schwefel. Angew. Bot. 6:276-300, 1924.

36. ———— Die chemischen Pflanzenschutzmittel, ihre Anwendung und Wirkung. 134 p. Berlin, 1926.

37. Weber, G. F. and Ramsey, G. B. Tomato diseases in Florida. Fla. Agr. Expt. Sta. Bul. 185:61-138, 1926.

38. Williams, P. H. Tomato leaf-mold. Expt. and Research Sta., Cheshunt, Herts, Ann. Rpt. (1925) 11:67-72, 1926.

PUBLICATION OF THIS DOCUMENT APPROVED BY THE COMMISSION
ON ADMINISTRATION AND FINANCE.

3M-4-'29. No. 5319.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 249 MARCH, 1929

The Plum Curculio In Apples In Massachusetts

W. D. Whitcomb

The plum curculio is the most injurious insect pest of apples in Massachusetts, frequently damaging more fruit than all other insects together. As a result of the heavy loss to fruit growers, studies of this insect were begun in 1926 in the eastern part of the State, and this bulletin reports the progress of the work to date.

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THE PLUM CURCULIO IN APPLES IN MASSACHUSETTS

By W. D. Whitcomb, Assistant Research Professor of Entomology

ORIGIN AND DISTRIBUTION

The plum curculio[1] is native to North America where it bred freely in the fruit of wild plums and hawthorns before the introduction of cultivated fruits. As early as 1736 it was reported as a serious pest of garden plums in the vicinity of Philadelphia, and since then it has been the subject of many reports under such names as cherry weevil, peach worm, little Turk, kerkelo, and little joker, as well as plum curculio. It appears to have been much more abundant and destructive along the Atlantic Coast, and although known to be present in the Mississippi Valley was not reported in large numbers until about 1850. Surveys in 1910 indicated that it had not become established west of the 100th meridian, and Quaintance and Jenne (9)[2] suggest that the western boundary of the humid area constitutes the barrier which governs its spread. Southern Canada and the Gulf of Mexico are the latitudinal limits.

IMPORTANCE IN MASSACHUSETTS

It is the unanimous opinion of those concerned with the fruit growing industry of Massachusetts that the plum curculio is the most injurious insect pest of apples in the state. Many orchardists believe that it is increasing its destructiveness each year in spite of their efforts to check it.

In some neglected and poorly cared-for orchards, every fruit on the tree at harvest has been damaged, with the greater part of the apples bearing the scars of three or more punctures. Even in orchards where an average spray schedule was followed, the proportion of blemished fruit frequently reached 30 per cent and occasionally 60 per cent.

During these studies as many as 310 curculios have been collected from one ten-year-old tree, and 3067 beetles have been taken from twenty-five such trees in an unsprayed orchard during the period when the beetles were entering the trees from hibernation.

A pest survey of the harvest fruit in forty-five Massachusetts orchards in 1928 showed the plum curculio to be the cause of more injury to apples than any other insect pest, the damage by it frequently exceeding that of all other insects combined.

As a result of the heavy loss to fruit growers, studies of this insect were begun in 1926 by the writer with headquarters at the Market Garden Field Station in Waltham, and this bulletin reports the progress of this work to date.

FOOD PLANTS

The fruit of the native wild plum is the natural food of the plum curculio, but that of cultivated plums is equally or more desirable, and the apple is also a very satisfactory host. The beetles attack practically all stone and pomaceous fruits and where these are grown in large quantities in the infested area the curculio is likely to become an important pest. This has been the case in the peach orchards of Georgia (11) and North Carolina (8), and the apple orchards of Connecticut (5) and Massachusetts.

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[1] *Conotrachelus nenuphar* Herbst, Order Coleoptera, Sub-order Rhyncophora, Family Curculionidae.

[2] Numbers in parentheses refer to Literature Cited on page 52.

In general, smooth skinned fruits are preferred, and in a mixed orchard cherries, prunes, apricots, and nectarines are heavily attacked. Feeding occurs on pears but the grubs do not develop in them. There are also records of unimportant feeding on grapes, huckleberries, and persimmons.

The preference of the curculio among commercial fruits of Massachusetts is indicated by the following record:

Table 1.—Number of Punctures in Different Fruits Made by 20 Plum Curculio Beetles Confined in Breeding Cages for 14 days. June 2 to 15, 1928.

	Plum	Apple	Cherry	Pear	Peach
Egg punctures	105	100	15	3	2
Feeding punctures	156	153	206	58	30
Total	**261**	**253**	**221**	**61**	**32**

Preference Among Apple Varieties.

All varieties of apples are attacked but those which blossom early and grow most rapidly after the petals fall are the first to provide attractive food and suitable locations for eggs, and consequently are the most severely injured. Among such varieties in Massachusetts are Duchess (Oldenburg), Yellow Transparent, and Gravenstein. Baldwin suffers moderate to severe injury, but McIntosh is less severely attacked than other commercial apples.

The rate of growth early in the season of five varieties, indicating their potential susceptibility to curculio injury, is shown by the following measurements of ten apples each in 1928, and offers a basis for comparison with other varieties. A larger number of measurements and a variety of growing conditions may change these figures considerably, but many field observations lead the writer to believe that the comparisons are substantially correct.

Table 2.—Rate of Growth of Apples. Waltham, Mass.

Variety	Average Diameter, Inches		
	June 8	June 15	June 22
Duchess	0.59	0.85	1.10
Baldwin	.45	.82	.98
Rhode Island Greening	.42	.73	.96
Williams	.39	.72	.95
McIntosh	.38	.62	.82

The potential susceptibility to curculio injury of the New England Seven (3) may be listed from greatest to least as follows: Gravenstein, Baldwin, Delicious[3], Wealthy, Northern Spy, Rhode Island Greening, and McIntosh.

Feeding activities during the summer and fall are concentrated on the early maturing varieties especially if they are allowed to become mellow on the tree, and more larvae develop to maturity in summer and fall apples than in winter apples.

The number of curculios collected on apple trees of different varieties indicates the choice of beetles, and in the following table the comparison of Delicious and Baldwin includes sufficient trees to be significant.

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[3] Delicious appears to be more deformed by curculio injury than Gravenstein or Baldwin.

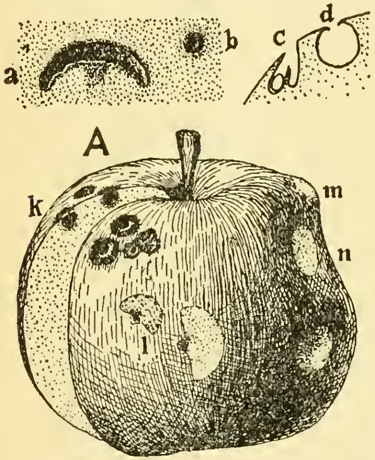
Table 3.—The Average Number of Beetles Collected from Different Varieties of Apple Trees by Jarring from May 10 to July 26.

Variety	Number of Trees		Average Number of Curculios per Tree	
	1927	1928	1927	1928
Delicious	13	16	75.6	72.6
Baldwin	10	8	160.4	133.3
Stayman	1		269.0	
Ben Davis	1	1	211.0	140.0

NATURE OF INJURY.

Injury to apples results from punctures by the beetles and from burrows by the larvae. There are four distinct kinds: namely, egg punctures, early feeding punctures, larval burrows, and late feeding punctures. The different kinds of punctures are clearly shown in Figure 1. In addition to these kinds of injury the beetles may eat small holes in the calyx and petals of buds and blossoms, and in Georgia (10) they feed extensively on peach leaves after the fruit has been harvested. Such injury is seldom seen in Massachusetts, and is of no economic importance.

Figure 1. Injury to Apple Caused by Plum Curculio. (After Fulton (4).)



a. Crescent Cut or Egg Puncture, surface view.

b. Early Feeding Puncture, surface view.

c. Egg Puncture, cross section.

d. Early Feeding Puncture, cross section.

k. Late Summer Feeding Punctures.

l. Scars Resulting from Crescent-shaped Egg Punctures.

m and n. Scars Resulting from Early Feeding Punctures.

An *Egg Puncture* is distinguished by a characteristic crescent-shaped cut through the skin of the young apple about ⅛ of an inch long and extending into the flesh of the fruit the same distance. Soon after it is made, the edges of the cut form a rough, hard, dark brown scab which enlarges with the growth of the apple until at harvest it becomes a russet scar from ¼ to ½ inch in diameter, somewhat irregular in shape but resembling an open fan and having little or no trace of the original cut. These scars are slightly raised and on some varieties, especially the Ben Davis, have the appearance of warts. Most egg punctures contain eggs but larvae do not hatch from all eggs and some larvae die before developing to maturity in the fruit. Consequently, many egg punctures are not followed by the usual larval burrows.

An *Early Feeding Puncture* is a spherical cavity extending about ⅛ of an inch into the flesh of the fruit. The entrance to this cavity is perfectly round and slightly smaller than the head of a pin. A scab and scar, similar to that following an egg puncture, develop except that the scar tends to be round and slightly smaller.

Most scars from both egg punctures and early feeding punctures are superficial and seldom decrease the keeping quality of the apple, but under the prevailing grading rules they reduce the fruit to the second or third grade.

The *Burrow of the Larva* extends through the fruit to the core, and causes the apple to fall early in its development. The tunnel resembles that made by the codling moth except that the feeding is more confined to the core.

Equally or more important than the injury by the larva is the fact that practically all apples, in which grubs develop, fall to the ground early in the summer. Many apples which are badly stung but contain no living grubs also fall. In the experimental orchard in 1927, 85 per cent of the fruit on unsprayed trees dropped before harvest. Eighty-three per cent of these "drops" showed curculio injury. On adjacent sprayed trees only 46 per cent of the fruit dropped and this fruit showed 12 per cent curculio injury. Other insects and diseases attacked the unsprayed fruit in this orchard, but the greater part of the excessive drop was attributed to curculio injury.

Tunnels in which the grubs have died close, leaving a thin brown line. Growth is slowed up or stopped in this region causing a depression in the outer surface of the fruit which considerably reduces its quality. Many of the apples injured in this manner remain on the tree.

Late Feeding Punctures are made principally by the fall-emerging beetles, although a few of the overwintering beetles may continue to feed at this time of year. The punctures through the skin are circular and about the size of a pinhead with a cavity in the flesh underneath equal in diameter to the length of the beetle's beak. The skin surrounding the entrance and covering the cavity turns black and the injury offers a favorable point for fungous infection. Many sound apples are injured by this type of feeding even though the beetles prefer mellow or blemished fruit.

DESCRIPTION (Non-Technical)

Like other beetles, the plum curculio passes through four stages of growth in its development, namely: the egg which is laid under the skin of the fruit, the larva or grub which feeds in the flesh of the fruit, the pupa or resting stage which is passed in an earthen cell, and the adult or beetle which develops from the pupa. Figure 2 illustrates the general appearance of the different stages.

The pearly white *Egg* is elliptical in shape, slightly less than 1/25 of an inch long and about half as wide. The smooth, shiny outer skin is moderately tough but so soft that the egg is easily crushed by the pressure from the growing fruit when not protected by the flap of the crescentic cut.

The full grown *Larva* is a plump, yellowish-white, legless grub from ¼ to ½ inch long. The body is curved toward the under side with fleshy lobes resembling swellings on the sides of the middle segments. The head is light brown, shiny, and about half as wide as the thickest part of the body.

The creamy white *Pupa* is approximately ¼ of an inch long. It has the general shape of the beetle with legs, beak, and partly grown wings folded tightly against the body. The black eyes are prominent.

The adult or *Beetle* is about 1/5 of an inch long and dark brown in general color with black and gray markings. Its wing covers are rough with a noticeable black hump near the middle of each. The whole body covering is hard and strong, and there is no easily distinguishable difference in the external appearance of the male and female. The beak extends forward and then downward nearly perpendicularly to the body.

LIFE HISTORY AND HABITS

Eggs

Number of Eggs Deposited

The number of eggs laid by one beetle varies greatly with the vitality of the individual. Weak specimens may lay less than ten eggs during their life, while 557 eggs (9), mostly in plums, have been reported from one very prolific female at Washington, D. C.

Records of five individual pairs confined with apples in cages at Waltham in 1927 showed an average of 175.75 eggs per female, and 254 eggs was the largest number deposited. The average number of days on which eggs were laid was 41.75, an average of 4.23 eggs per day of laying. The greatest number of eggs laid in one day was 13.

Length of Incubation Period of Eggs

The number of days between the laying of the egg and the hatching of the larva varies from 4 to 11, depending largely on the temperature. The first eggs laid in the spring always had a longer incubation period than the later ones. The duration of this period throughout the season in the insectary at Waltham follows:

Table 4.—Length of Incubation Period of Eggs of the Plum Curculio Waltham, Mass.

Year	Number of Eggs	Incubation Period—Days		
		Maximum	Minimum	Average
1926	4040	11	5	7.6
1927	2696	10	4	7.57
1928	2356	10	4	5.74

Larva

Habits of Newly Hatched Larva

In the apple the young larva begins tunneling into the flesh of the fruit very soon after it hatches from the egg. Observations in the insectary indicate that normally they are out of sight two hours after they hatch. The path of the tunnel through the fruit may be exceedingly tortuous but a large number of grubs burrow straight to the core.

Many small larvae die in the tunnels before reaching the core. In apples, the pressure of the growing fruit is the main cause but other reasons undoubtedly contribute to this mortality, which is especially noticeable in larvae hatching from eggs laid late in the oviposition period.

The writer has never seen an apple on the tree from which a curculio larva has emerged unless that apple was ready to fall while small.

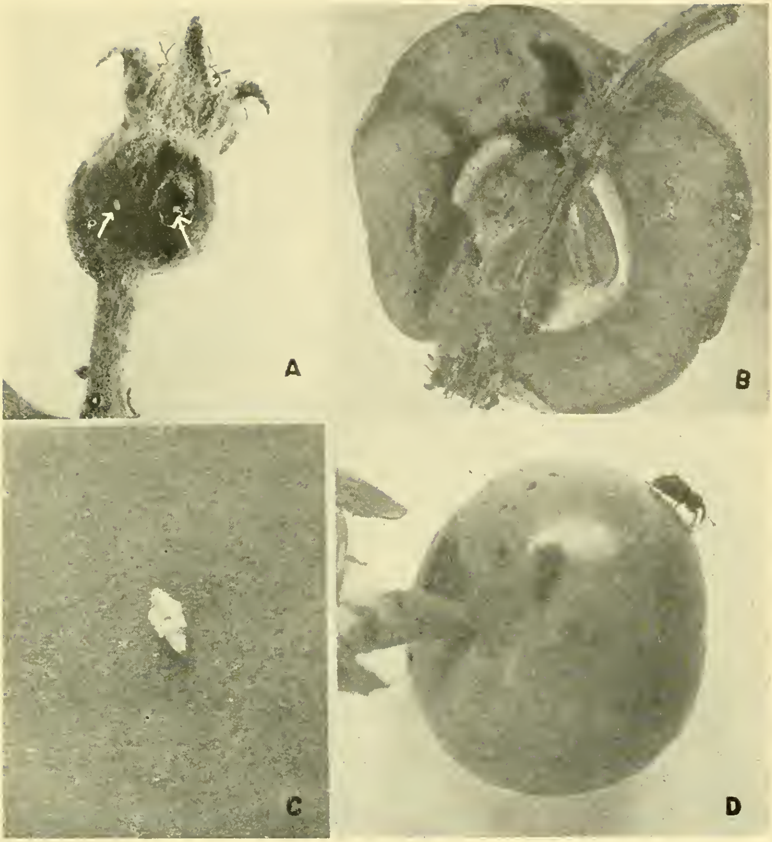


Figure 2. Life History of the Plum Curculio, Showing Different Stages. Enlarged about 1½ x. (Photo by H. A. Wilson.)
A. Eggs in Apple.
B. Larva in Apple.
C. Pupa.
D. Adult or Beetle.

Feeding of Larva in Apple

While the larva is feeding and growing it molts or sheds its skin four times requiring about 16 days for this development in the fruit. In 1927 one individual lived fifty-three days in the fruit, and five others stayed there more than forty days, but that is unusual as shown by the summary of the insectary studies of this period for three years in Table 5.

Table 5.—The Number of Days the Larvae of the Plum Curculio Remain in Apples after Hatching. Waltham, Mass.

Year	Number of Larvae	Growth of Larvae in Fruit—Days		
		Maximum	Minimum	Average
1926	1430	34	7	15.87
1927	861	53	10	16.79
1928	908	28	7	15.78

When the larva is ready to leave the fruit, it emerges from a round hole usually through the side, and by this time the apple is shrivelled or rotted so that the flesh around the hole collapses.

Pupa

Depth of Cell in Soil

When the larva leaves the fruit it enters the ground and forms a cell. Practically all of these cells have been found three inches or less below the surface of the soil although where hay is spread under the trees, cells have been found as deep as eight inches below the top of the mulch. In these cells the larvae transform to pupae slowly.

Length of Time Spent in Soil

In Michigan (9), it was found that an average of 12.03 days or 36 per cent of the total time in the soil was passed as a larva before actual pupation occurred. In the studies at Waltham no record of this period was obtained, but it was found that the total time in the soil ranged from 17 to 55 days, averaging about 30 days. In 1926 the average time spent in the soil by reared specimens was 31.46 days, and by field collected specimens 31.88 days. A summary of the records for three years follows.

Table 6.—Number of Days Spent in the Soil by the Plum Curculio as Larva, Pupa, and Adult. Waltham, Mass.

Year	Number of Individuals	Time Spent in Soil—Days		
		Maximum	Minimum	Average
1926	1546	54	17	31.75
1927	2102	55	22	30.96
1928	2607	51	21	29.50

There is much evidence that development of the insect in the soil is influenced by moisture, and that if the soil is dry the time spent in the soil is greatly prolonged even causing death. Heavy rain or watering during the time the beetles are emerging immediately increases the number appearing, but the rainfall in New England in addition to the usual sod or mulch covering under the trees ordinarily furnishes sufficient moisture for normal emergence.

Adult

Upon leaving their winter quarters the beetles fly to the trees and mating begins soon afterwards. While the weather is cool, they remain very quiet usually perched in the crotch of a twig or in the roll of unfolding leaves and blossoms. They are rather strong fliers, frequently moving from one tree to another, but are clumsy in "taking off" and landing. When disturbed they play "possum", folding their legs against their body in a most lifeless manner and in this position often fall to the ground where they remain motionless for many minutes.

Egg Laying

Eggs are laid only in the fruit[4], and this activity takes place during both night and day. In performing this operation, the beetle first prepares a tunnel under the skin of the apple almost parallel to the surface and about 1/16 of an inch long. Turning around, she drops an egg into this and then pushes it to the end of the tunnel with her beak. Starting near the entrance to the egg tunnel, she cuts sideways and somewhat obliquely to the core in both directions until a crescent shaped slit about 1/10 of an inch deep is made, leaving the egg in a flap of the fruit as shown in Figure 1. This flap shrivels before the cut is healed and relieves any pressure on the egg. In apples, the majority of the eggs are laid in the side of the fruit, but in plums a large number of the first eggs are frequently placed near the tip. The number of eggs laid is discussed on page 30, and several counts showed that more than 90 per cent of the egg punctures contained eggs.

Feeding

Before the fruit is set, small, round or irregular areas may be eaten in petals and at the base of the stamens, but in captivity the majority of the beetles prefer to wait until the fruit is available. In 1927 the average number of feeding punctures by five pairs of beetles was 236.4 per pair, with a maximum of 336 and a minimum of 170. One pair fed on 85 different days, and the average number of days when feeding took place was 63.

Proportion of Egg to Feeding Punctures

Due to the greater length of the feeding period the total number of feeding punctures exceeds the number of egg punctures. The insectary records show that feeding punctures constituted 64 per cent of the total punctures in 1926; 78 per cent in 1927; and 83 per cent in 1928. During the oviposition period the egg punctures practically equal the feeding punctures, and on some days exceed them.

Length of Life of Beetles

The beetles emerge from their earthen cells in August and September, hibernate, and enter the trees the following spring. Under insectary conditions, about one-half of them are usually dead by the first of September, approximately one year after they emerged (See Table 7.) Many of the others live until late October, and in 1928 ten beetles were alive when placed in hibernation on November 20, after surviving several days when the temperature dropped to 20° F.

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[4] Eggs have been found in black knot cankers on plums.

Table 7.—Percentage of Caged Beetles Which Remained Alive in the Insectary at Different Dates in 1927 and 1928. Waltham, Mass.

Date	Beetles Alive, Per Cent	
	1927	**1928**
June 15	86	92
July 1	80	83
July 15	72	82
Aug. 1	57	76
Aug. 15	38	65
Sept. 1	22	57
Sept. 15	13	51
Oct. 1	9	44
Oct. 15	7	38
Nov. 1	1	26
Nov. 15	0	17

Feeding Injury in the Fall

Fall feeding punctures by the beetles which emerge in the late summer are much fewer than those made by the overwintering beetles in the spring. In 1927 the record of three typical cages of ten beetles each shows that, although their feeding period was only one-third longer, the overwintering beetles made nearly four times as many feeding punctures as the fall-emerging beetles, in addition to having an average of 175 egg punctures per cage. (Table 8.)

Table 8.—Comparison of the Number of Punctures in Apples Made by Overwintering and Fall-emerging Beetles of the Plum Curculio in 1927. Waltham, Mass.

Date Feeding Began	Number of Beetles	Number of Egg Punctures	Number of Feeding Punctures	No. of Days from First to Last Feeding
Overwintering Beetles				
May 31	10	77	742	122
June 3	10	345	760	129
June 14	10	103	493	117
Average	**10**	**175**	**665**	**122.7**
Fall-Emerging Beetles				
July 30	10	0	148	67
Aug. 1	10	0	268	73
Aug. 2	10	0	162	77
Average	**10**	**0**	**192.7**	**72.3**

Number of Generations

There is one generation of the plum curculio annually in Massachusetts. Throughout these studies all attempts to rear second generation individuals in the insectary have been unsuccessful. Unfavorable climatic conditions are not altogether the reason for this, since in 1927 the first beetle of the summer brood emerged three days before the last egg was laid by the overwintering beetles, and in 1928 the first beetle appeared eighteen days before the last egg was laid.

Choice of Hibernating Quarters

The beetles apparently prefer to spend the winter under leaves rather than under hay or stones, and many observations have shown them to be more abundant in the spring on trees adjacent to woodland than elsewhere. Apparently they will fly at least half a mile if necessary to find their favorite cover, returning the same distance to the trees in the spring. On October 4, 1927, 500 beetles were liberated in a cage over an apple tree containing several different types of winter covering arranged in easily accessible piles. On November 27, after a thorough examination, 209 or 41.8 per cent of the beetles were recovered, the majority being found under leaves, as shown in Table 9.

Table 9.—Type of Cover Preferred by Hibernating Beetles of the Plum Curculio. Waltham, Mass., 1927

Type of Cover	Curculios Recovered		
	Number	Per Cent	
Maple leaves	146	*69.86*)	*76.08*
Apple leaves (from tree in cage)	13	*6.22*)	
Dried grass	33	*15.79*	
Stones	11	*5.26*	
Corrugated paper	4	*1.91*	
Screen sides of cage	2	*0.96*	

Time Required for Development from Egg to Adult

Approximately 55 days are required by the plum curculio to develop from a newly laid egg to an adult. Cool weather, unfavorable food, and lack of sufficient soil moisture may lengthen this period, while some individuals develop more quickly. The averages for three years are shown in Table 10.

Table 10.—Average Time Required by Plum Curculio to Develop from Egg to Adult in Breeding Cages

Year	Egg and Larva in Fruit—Days	Larva, Pupa and Adult in Soil—Days	**Egg to Adult—Total Days**
1926	23.47	31.75	**55.22**
1927	24.36	30.96	**55.32**
1928	21.54	29.50	**51.04**

SEASONAL HISTORY.

Occurrence of Beetles in Trees.

The first of the overwintering beetles are found in the trees when the blossom buds are showing pink. They are not abundant early in the season, and the greatest proportion of the total number collected in any season before petal-fall was 1.6 per cent in 1927. As shown in Figure 4, the majority of those collected by jarring[5] were found between June 10 and 30, with the

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[5] The method of jarring referred to consists of placing under the tree two cloth covered frames each 6x12 feet, with a square hole cut in the center for the tree trunk, and bumping the larger branches sharply with the padded end of a pole. The beetles fall to the sheets where they are picked up and counted. In this work the jarring was done each Tuesday and Friday morning about daybreak, regardless of the weather, but it was noticeable that the beetles were jarred from the trees with more difficulty when the trees were wet.

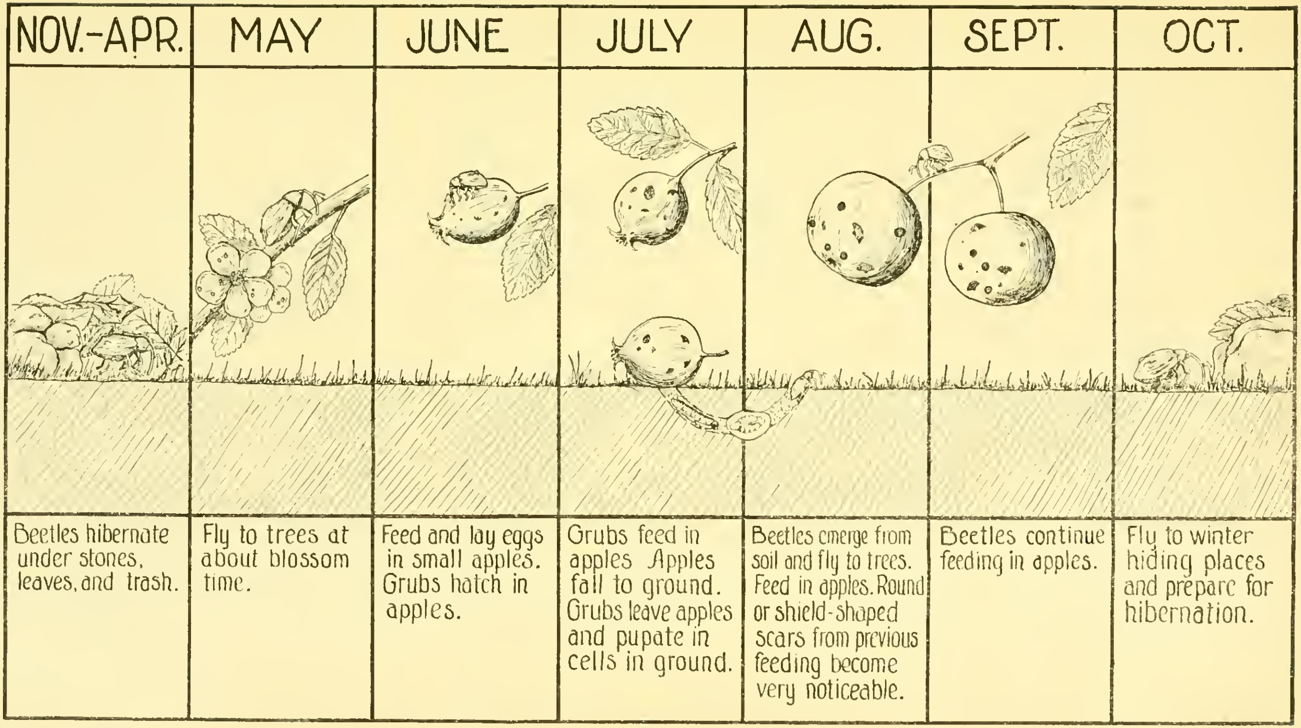
NOV.-APR.
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
Beetles hibernate under stones, leaves, and trash.
Fly to trees at about blossom time.
Feed and lay eggs in small apples. Grubs hatch in apples.
Grubs feed in apples Apples fall to ground. Grubs leave apples and pupate in cells in ground.
Beetles emerge from soil and fly to trees. Feed in apples. Round or shield-shaped scars from previous feeding become very noticeable.
Beetles continue feeding in apples.
Fly to winter hiding places and prepare for hibernation.

Figure 3. The Seasonal History of the Plum Curculio in Apples in Massachusetts.

largest collections ranging from June 10 in 1927 to June 22 in 1926. Stragglers continued in the trees until the last week in July each year, although it is probable that some of the later collections included insects which migrated from unjarred trees.

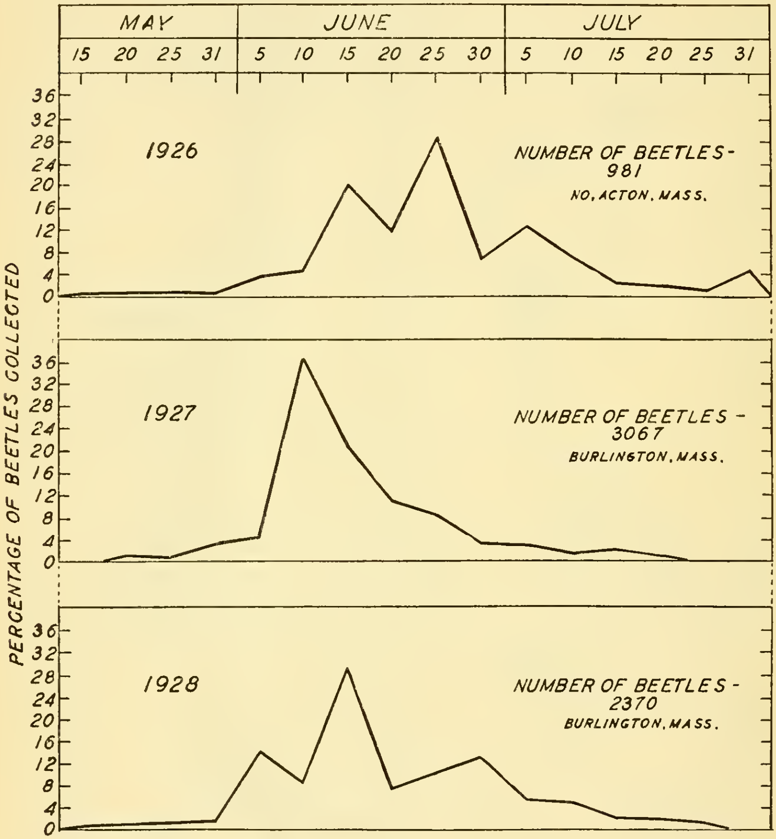

Figure 4. Time of Appearance of the Plum Curculio in Apple Trees in the Spring, as Obtained from Jarring Records.

Period of Oviposition

During the three years of study, oviposition has begun about June 1. By June 15 this activity has increased to normal proportions and the number of eggs deposited continued to be large until July 15. As shown in Figure 5, the greatest number of eggs was laid between June 21 and June 30 each year, usually following closely the appearance of the greatest number of beetles in the trees. Only in 1928 were eggs found after August 1 and many of those laid during the last week of this period failed to develop. The beetles are quite resistant to climatic changes and the number of eggs laid daily does not vary greatly with the fluctuations in temperature. Normal weather conditions are the most favorable for curculio activity.

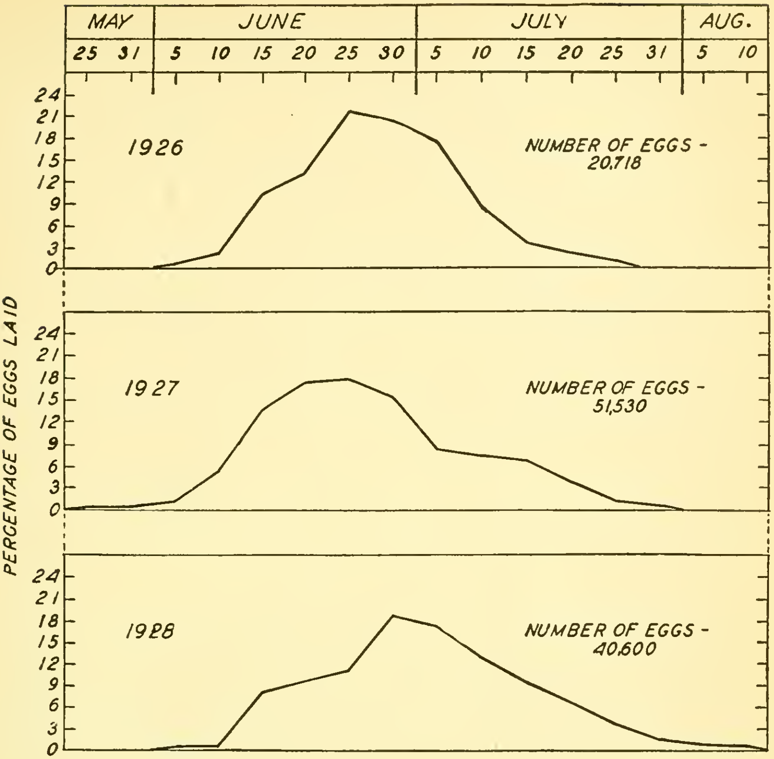

Figure 5. Time of Oviposition by Plum Curculio Beetles in Breeding Cages in the Insectary, Waltham, Mass.

The number of eggs used in this diagram is computed from a daily record of the actual number of eggs laid by 10 beetles retained from each semi-weekly collection by jarring on the dates shown in Figure 4.

Feeding Period of Beetles.

Feeding punctures in the fruit are first found in the apples during the last week in May. From then on they increase rapidly until about June 21-25 in which period the greatest number was made in 1926 and 1927. As shown in Figure 6, rather constant heavy feeding continues to the end of July, and in 1928 the actual maximum was reached July 26. Under favorable living conditions, such as were provided in the insectary, some of the overwintering beetles continue feeding until cold weather. This was especially true in 1928 when feeding was observed as late as November 17. After September 1, however, feeding by the overwintering beetles is insignificant and in the orchard it cannot be distinguished from feeding by fall-emerging beetles.

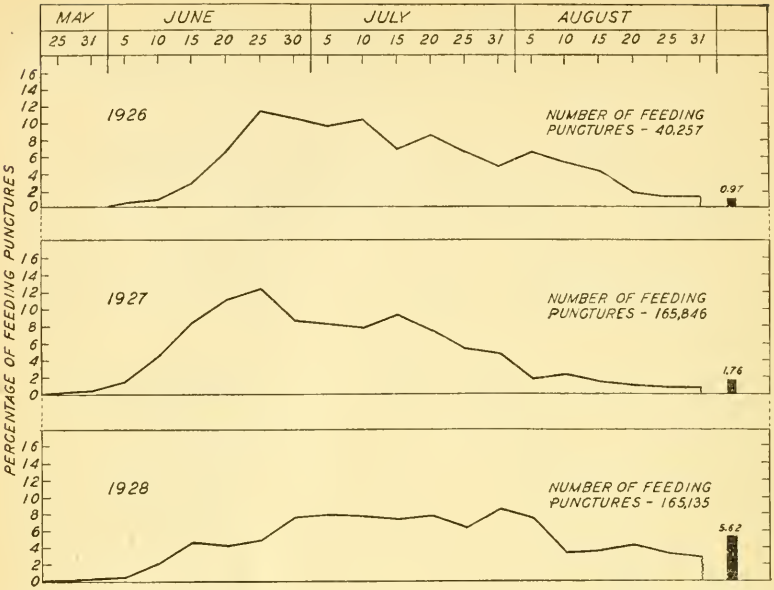

Figure 6. Time of Occurrence of Feeding Punctures in Apples by Overwintering Plum Curculio Beetles in the Insectary, Waltham, Mass.

The number of feeding punctures used in this diagram is computed from a daily record of the actual number of feeding punctures made by 10 beetles retained from each semi-weekly collection by jarring on the dates shown in Figure 4. The solid areas in the diagram indicate the total percentage of feeding punctures which occurred after the last date shown in the graph. The last feeding puncture was made on September 1 in 1926, on October 15 in 1927, and on November 17 in 1928.

Time that Larvae Leave the Fruit.

Figure 7 shows that larvae of the plum curculio first left the apples to enter the soil between June 25 and 30 in 1926 and 1928, and soon afterward in 1927. The greatest number of larvae left between July 10 and 20 each year, and with the exception of two individuals in 1927 all of them entered the soil before September 1. This activity has been very constant during the three years of observation. A more detailed report on the emergence of larvae from dropped apples in the orchard is given in Table 12.

Emergence of Beetles from Soil.

Beginning the last ten days of July, the beetles emerge from the soil in increasing numbers until they reach a maximum between August 6 and 20. After this point the number decreases rapidly with a few stragglers continuing to appear until early October, as shown in Figure 8. Emergence has been quite constant in these studies. The beetles seek their hibernating quarters between September 15 and October 1, depending on the weather.

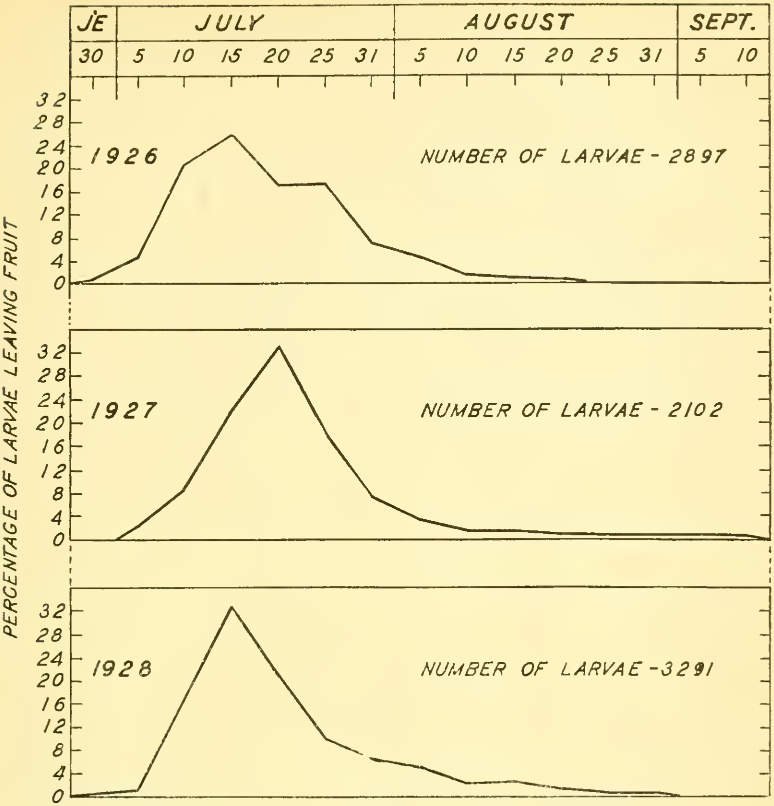

Figure 7. Time when Larvae of Plum Curculio Left the Fruit in Breeding Cages in the Insectary, Waltham, Mass.

NATURAL CHECKS ON ABUNDANCE

Climatic Conditions

Several observations in Massachusetts indicate that 60 per cent to 75 per cent of the plum curculio beetles die in their hibernating quarters, the number depending on the amount of snow and the frequency of sudden changes from high to low temperatures. This percentage may seem high in view of the abundance of beetles in the orchards in the spring, yet in 1927-28, an unusually open winter, several cages of beetles with a six-inch covering of leaves, some exposed and others protected by a roof suffered 90 per cent to 100 per cent mortality.

During the summer, when infested fallen apples are exposed for two or three days to a bright hot sun, many of the larvae die in the fruit. However, the shade from the tree and the protection from grass or mulch usually eliminate high mortality from this cause.

Baking and packing the soil around the cells in which the insects are pupating prevents many of the beetles from emerging, but again such conditions seldom occur in this state.

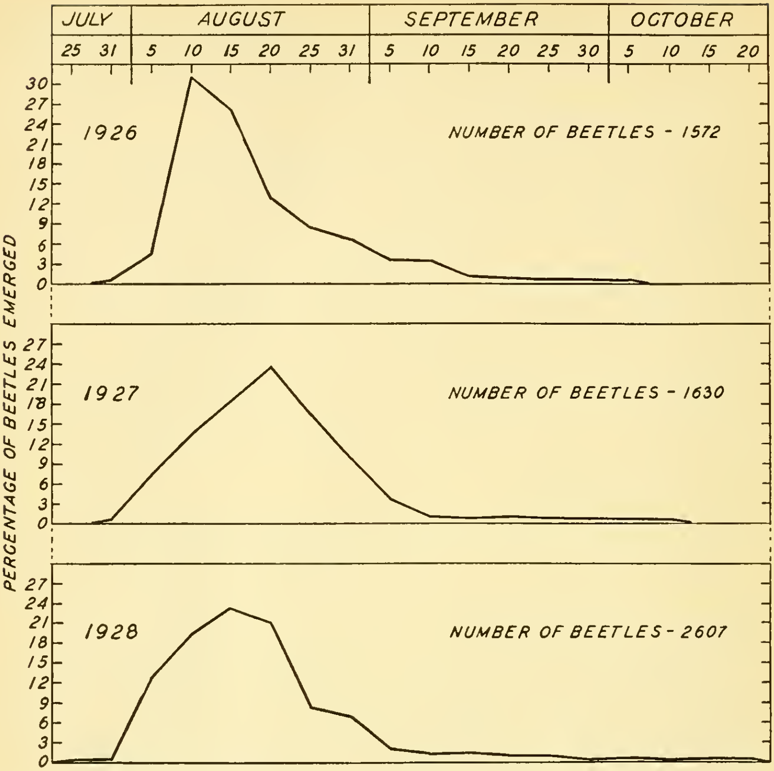

Figure 8. Time when Plum Curculio Beetles Emerged from the Soil in Breeding Cages in the Insectary, Waltham, Mass.

Birds and Predatory Insects.

Although plum curculio beetles are hard and apparently unpalatable food, the U. S. Biological Survey (9) has found them in the stomachs of orioles, grosbeaks, barn swallows, vireos, and thrushes. However, these birds are not sufficiently abundant to provide a noticeable check on this insect.

The grubs are known to be eaten while in the ground by various ground beetles and ants, while lacewings attack the larvae in the fruit, but no outstanding instance of a significant check by predaceous insects has been brought to the attention of the writer in Massachusetts.

Parasites.

During the observation and rearing of several thousand plum curculio in 1926 and 1927 at Waltham, no parasites were found. In 1928, however, six specimens of a tiny four-winged parasitic fly, tentatively determined as *Triaspis curculionis* Fitch, were reared from a large lot of field collected larvae. Records of this parasite in other states show a maximum parasitism of 25 per cent (9), although the general average is less than 3 per cent.

CONTROL

Cultural Practices

Destruction of Beetles in Hibernating Quarters

By burning the leaves and trash which have accumulated along fences, walls, brush heaps, undergrowth, and adjacent woods, many beetles are killed in their hibernating quarters. Burning may be done at any time in the winter or early spring but is most effective when the trash is dry enough to make a hot fire close to the ground. Burning about 300 yards into woods adjoining orchards is recommended where possible. Ample fire-fighting apparatus, such as fire extinguishers, a power sprayer, rakes and brushes should be available to keep the fire under control. Experiments showing the effect of burning have not been made in Massachusetts, but an idea of the results which may be expected can be obtained from an experiment in North Carolina (8) which is summarized in Table 11.

Table 11.—Comparison of Number of Beetles Jarred from Three Blocks of Peach Trees Adjacent to Woods and Field
Aberdeen, N. C. 1922

Location of Trees	Dates Jarred	Number of Trees	Number of Beetles
Opposite unburned woods	Mar. 14 to May 9	44	730
Opposite burned woods	Mar. 14 to May 9	42	265
Next to field	Mar. 14 to May 9	39	111

Destruction of Larvae in Dropped Apples

All apples infested with living plum curculio larvae fall to the ground and the larvae remain in the apples approximately ten days after they fall. From an entomological viewpoint the destruction of the grubs in the dropped apples is a perfect method of controlling this insect even to the point of elimination, but from the standpoint of the fruit grower the labor and expense of picking up all of the infested apples at the proper time gives this operation a decidedly unpractical aspect. However, the positive destruction of the insect and the knowledge that for a certain period about July 1 the dropped apples under a heavily infested tree contain an average of more than one larva per apple (See Table 12) gives this operation great value even from a practical standpoint.

Cutting grass under the tree, clean cultivation, and a liberal hay mulch aid greatly in reducing the cost of picking up apples. In 1928 one progressive fruit grower in eastern Massachusetts picked up an average of three bushels per Yellow Transparent tree, capable of bearing twenty bushels of mature apples, at an average cost of $1.00 per tree without preparation for the work. The estimated damage by the plum curculio on these trees exceeded $5.00 per tree. By cutting the grass and better organizing the work, he plans to reduce the cost greatly in the future.

As shown in Table 12, more apples fall before June 28 than after, and from these apples the largest number of larvae emerge. However, the apples which fall during the next ten days contain the greatest number of larvae per apple and consequently should be picked up very carefully. In late June and early July the first larvae emerge about six days after the apples fall, and about four days later they are leaving the fruit in large numbers so that gathering them after this time has little value. Three collections of "drops" are usually sufficient to destroy the majority of the grubs in

Table 12.—Number of Larvae of Plum Curculio in Dropped Apples Picked up under an Unsprayed Duchess Tree, Waltham, Mass.

Period when Apples Fell	Number of Apples	Larvae Emerged		Date when First Larvae Emerged	Date Apples Should Be Picked up and Larvae Killed
		Total Number	Av. per Apple		
1926					
Before June 24	756	520	0.69	June 30	July 2
June 24-28	351	384	1.09	July 4	July 6
June 28-July 1	170	245	1.44	July 9	July 10
July 1-5	131	126	0.96	July 11	July 12
July 5-8	108	112	1.04	July 18	July 18
July 8-12	42	32	0.76	July 25	July 25
July 12-15	30	20	0.67	July 27	July 27
July 15-19	39	23	0.59	July 25	July 27
1927					
Before June 19	453	196	0.43	July 3	July 2
June 19-23	722	289	0.40	July 4	July 8
June 23-26	460	197	0.43	July 4	July 6
June 26-30	161	139	0.86	July 8	July 12
June 30-July 3	215	204	0.95	July 8	July 13
July 3-6	131	122	0.93	July 11	July 16
July 6-10	142	66	0.47	July 13	July 17
July 10-13	77	19	0.25	July 14	July 18
July 13-17	75	6	0.08	July 18	July 18
July 17-21	16	3	0.19	Aug. 4	Aug. 4
1928					
Before June 21	200	156	0.78	July 4	July 5
June 21-27	994	817	0.82	July 4	July 5
June 27-July 1	424	623	1.47	July 4	July 10
July 1-4	567	514	0.91	July 6	July 13
July 4-8	135	145	1.07	July 12	July 16
July 8-11	176	104	0.59	July 15	July 17
July 11-15	62	14	0.23	July 29	July 29
July 15-18	45	6	0.13	July 31	July 31

infested fallen apples. The first collection should be made as soon as sufficient "drops" have accumulated to warrant the labor, usually the last week in June; followed by two additional collections at weekly intervals.

When the apples are gathered, they should be treated so that every grub in them is killed. The usual practice is to dump them in a pit, adding a liberal covering of quicklime to each foot of apples and covering all with at least fifteen inches of packed soil. Other effective treatments are boiling the apples, burning the apples, and feeding them to livestock.

At least one fruit grower has observed a marked decrease in curculio injury following the pasturing of sheep in the orchard while the apples are falling, and similar benefits to a less degree have been noticed where poultry or hogs were penned in the orchard.

Destruction of Larvae and Pupae in the Soil

Large numbers of plum curculios are in the pupal stage in the top three inches of soil between July 20 and August 1 in Massachusetts. These pupae are delicate and, therefore, easily crushed. During this period cross cultivation with an extension disc harrow reaching close to the tree trunks kills many of these pupae. In heavy packed soil this cultivation will be more effective than in sandy soil. Many fruit growers object to cultivation at this time because of the danger of stimulating later growth and consequent winter injury. Clean cultivated orchards usually suffer less injury by the plum curculio than sod orchards.

Summary of Cultural Practices.

In orchards where the plum curculio continues to inflict severe injury, all of the above cultural operations in addition to careful spraying may be necessary to reduce the injury to a commercial minimum. Where injury is slight, some or all of the cultural practices can be eliminated and satisfactory control obtained by spraying alone. The cultural operations are valued in the following order: (1) destruction of larvae in dropped apples, (2) burning hibernating quarters, and (3) cultivation while the insects are in the soil. Burning of hibernating quarters reduces the curculio population during the following spring, but the effect of the other operations is not apparent until the second season.

Treatment of Soil with Insecticides to Kill Larvae and Pupae.

In laboratory experiments using 200 larvae and pupae of the plum curculio under natural conditions in exposed soil cages, carbon disulfide emulsion (7), 1 quart in 49 ¾ gallons of water (½ per cent), applied to the soil at the rate of three pints per square foot, killed 99.5 per cent of the insects, and when applied at the rate of one quart per square foot, 90 per cent succumbed. This emulsion which is extensively used in the control of Japanese Beetle larvae is prepared by dissolving one part (liquid measure) resin fish oil soap in three parts of water to which is added slowly with vigorous stirring ten parts of carbon disulfide.

In the orchard this treatment is practical only in cases of severe infestation and under a few selected trees. It should be applied between July 25 and August 5, and is more effective when the soil is moist so that the emulsion easily penetrates at least three inches. The materials cost about twenty cents per tree of average size.

When apples containing living eggs and larvae were immersed in this emulsion for ten minutes, the number killed was only slightly greater than the natural mortality in untreated apples.

Spraying

With a normal crop of fruit, efficient spraying will give commercial control of the plum curculio when the number of insects averages less than 25 per tree of average size. When there are more than 25 beetles per tree, the number of apples punctured by the beetles while obtaining a fatal dose of poison usually represents a commercial loss, even though the fruit is protected by the most effective spraying practices now available. A small crop of fruit suffers more injury than a large crop.

Laboratory experiments have shown that the majority of beetles feeding on apples sprayed with the most effective formulae are killed in less than eight days, and that during the most active period of their life they make from two to five punctures per beetle in the poisoned fruit before dying.

Method of Application

Thoroughness is the most important factor in the spraying operation. All sides of each fruit should be covered with a film of poison and to do this the tree must be sprayed from the inside as well as the outside. An extension rod equipped with one or two angled nozzles delivering a uniform mist-like spray is the best means of applying the poison, but a spray gun used intelligently with at least 200 pounds pressure will do effective work on a calm day. On a windy day, spraying should be done only in emergencies, using rods which enable the operator to reach all parts of the tree with the spray. In the spraying experiments extension rods and spray guns were interchanged to fit the weather conditions. Adequate machinery in good repair, and an ample supply of insecticides, fungicides, oil, gasoline, and hose connections should be quickly available to avoid delays and ineffective application.

Time of Application.

Early sprays such as the delayed dormant, pre-pink, and pink are very necessary for combating other pests but give little or no protection against the plum curculio, since the few which are in the trees during these applications feed very sparingly on the buds and leaves. In fact, fruit counts in the experimental orchard in 1926 showed just as good protection where the pink spray was omitted as where it was applied.

The *Calyx Spray* is relatively unimportant in combating the plum curculio, nevertheless it is the most important single application (1) in the apple spray schedule in Massachusetts and should never be omitted. At this time from 2 to 5 per cent of the beetles have gone to the trees, and feeding in the developing fruit begins soon after. The later this spray is applied, in the period between petal-fall and the closing of the calyx lobes (usually ten days), the more effective it is against the plum curculio, but it should never be delayed so that it fails to serve its main purpose of filling the calyx cup of the apple with poison.

The *7-Day Spray* (*1st Curculio*) applied about 7 days after the proper time for the calyx spray is the most effective application against this insect. At this time beetles are actively feeding and laying eggs and the apples are growing rapidly. Individual fruit growers can time this application in their own orchards by spraying as soon as possible after the first punctures are seen. Invariably, however, this will occur about the time the largest of the young apples become ½ inch in diameter. In some seasons frequent heavy rains immediately following this application decrease its effectiveness and make it advisable to repeat the treatment at the first satisfactory opportunity especially on the more suscepible varieties.

The *3-Weeks Spray* (*2nd Curculio*) is applied about three weeks after the proper time for the calyx spray. Under natural conditions the largest number of punctures are made in the fruit about this time. When the number of beetles is small, and previous sprayings have been particularly effective, this application may be less important but it is always advisable. The value of the second curculio spray under certain conditions is well illustrated in Table 16 where the percentage of fruit injured was 13 per cent less in the plat to which the 3-weeks application was made than where it was omitted.

In applying the calyx, 7-day, and 3-weeks sprays, much benefit will result from timing the applications according to the development of the varieties. The young fruit of such varieties as Duchess, Yellow Transparent, and

Gravenstein develops rapidly, and should be sprayed before such late developing varieties as Northern Spy and McIntosh.

Materials.

Stomach Poisons. Lead arsenate in the powdered form is the standard insecticide in use for the control of the plum curculio as well as other leaf or fruit-eating orchard insects. Laboratory experiments with this poison have shown that beetles feeding on sprayed apples die in two to ten days, and orchard spraying experiments have indicated commercial control from its use in a well-timed spray schedule. Two pounds of powdered lead arsenate in each 50 gallons of water is the most practical dosage in curculio sprays for Massachusetts apple orchards.

Calcium arsenate contains a higher percentage of the active agent, arsenic oxide, than lead arsenate and has been slightly more effective under laboratory conditions when used in equal parts by weight. On orchard trees calcium arsenate is generally used with equal or more parts of lime to prevent foliage injury and fruit russeting, but the lime tends to reduce its effectiveness. No orchard experiments with calcium arsenate have been conducted on this project but recent work in New Hampshire (2) has shown that 1½ pounds of calcium arsenate in lime-sulfur solution diluted to 1 gallon in each 50 gallons of water, without additional lime, can be used with more safety than lead arsenate in the same formula. Until further work has been done, however, lead arsenate is preferred to calcium arsenate for plum curculio control in Massachusetts.

The results of some of the laboratory experiments in comparing these materials are shown in Table 13.

Table 13.—Effect of Lead Arsenate and Calcium Arsenate Sprays on the Control of Plum Curculio Beetles on Apples. June 11—28, 1928.

Insecticide	Number of Curculios at Beginning	Number of Curculios Dead after 8 Days	Average Number of Punctures per Beetle in Apples when Experiment Closed
Lead Arsenate 1½ lbs. Water 50 gals.	10	8	7.8
Lead Arsenate 2 lbs. Water 50 gals.	10	8	4.4
Calcium Arsenate 1½ lbs. Water 50 gals.	10	9	2.5
Calcium Arsenate 2 lbs. Water 50 gals.	10	10	3.9
Calcium Arsenate 1½ lbs. Hydrated Lime 3 lbs. Water 50 gals.	10	5	7.3*
Calcium Arsenate 2 lbs. Hydrated Lime 4 lbs. Water 50 gals.	10	5	6.8*
None	50	0	30.1*

* Estimated—Apples dried or covered with punctures, making accurate count impossible.

Stickers. The addition of stickers or spreaders to the poison has consistently reduced the number of days necessary to kill the beetles as well as the number of punctures made in sprayed fruit.

Light pressed Menhaden Fish Oil (6) proved to be the most effective sticker and its use seems practical. In laboratory experiments the number of punctures in the fruit was generally decreased from one-third to one-half by its use, and the beetles died more quickly than when feeding on lead arsenate alone. In orchard experiments in 1927, the lead arsenate—fish oil combination gave 15.52 per cent better control than the lead arsenate—calcium caseinate formula. It is recommended that 4 liquid ounces of fish oil be used for each pound of powdered lead arsenate regardless of the amount of spray solution, but more than 1 pint (16 ounces) is unnecessary in 100 gallons of any spray formula used on orchard trees. The fish oil should always be added after the poison has been thoroughly agitated in the solution for several minutes, and the agitation continued until the two materials are thoroughly mixed. This rapidly drying oil is available in most cities and can be purchased in Boston for about 80 cents a gallon, the price varying with the quantity. Raw linseed oil may be satisfactorily substituted but is more expensive.

A cheap grade of *molasses*, such as is used for feeding cattle, when added to the spray at the rate of 1 gallon in 100 gallons, increased the effectiveness of the poison by 16.58 per cent in an orchard heavily infested by the plum curculio in 1927, and also made the poison more effective in several laboratory experiments. The cost is usually greater than that of fish oil, and it is less desirable.

Calcium Caseinate, manufactured under several commercial names, is generally used in all sprays in which lead arsenate and lime-sulfur solution are combined, to reduce undesirable chemical action between these materials. Many experiments throughout the country have failed to show conclusively that it increased the effectiveness of lead arsenate, yet in several laboratory tests on this project it had a slight value. It is used at the rate of 1 pound in each 100 gallons of spray, and when mixed with lead arsenate and lime-sulfur solution should be added to the spray between the active materials.

A comparison of the value of the various stickers with lead arsenate, under laboratory conditions, for combating the plum curculio is given in Table 14.

Combination Sprays. Since it is necessary to secure protection from apple scab and other fungous diseases as well as from insect pests, fungicides are combined with the poisons wherever possible. Orchard spraying experiments in 1926 indicated that the lead arsenate-calcium caseinate-lime-sulfur solution formula was not as effective against the plum curculio as when the lime-surfur solution was omitted. Later observations failed to confirm this belief, and any difference in the efficacy of these combinations is not considered significant as is shown in Table 15. Under normal conditions, however, it is believed that the fungicide can be safely omitted from the 7-day spray, at least on varieties other than McIntosh.

Orchard Spraying Experiments.

In conjunction with the laboratory experiments, spraying experiments were conducted in a four-acre orchard at North Littleton, which was isolated from other bearing apple trees. The varieties in this orchard are McIntosh, Baldwin, and Wealthy, and the count trees included some of each. The control of the plum curculio in this orchard by spraying was very good in spite of a heavy infestation, yet indoubtedly the percentage of blemished

Table 14.—Effect of Lead Arsenate Sprays, with and without Stickers, on the Control of Plum Curculio Beetles on Apples, June 11-28, 1928.

Insecticide and Sticker	Number of Curculios at Beginning	Number of Curculios Dead after 8 Days	Average Number of Punctures in Apple per Beetle when Experiment Closed
Lead Arsenate 1½ lbs. Fish Oil 6 oz. Water 50 gals.	10	10	6.2
Lead Arsenate 2 lbs. Fish Oil 8 oz. Water 50 gals.	10	10	2.5
Lead Arsenate 1½ lbs. Calcium Caseinate ½ lb. Water 50 gals.	10	8	5.2
Lead Arsenate 2 lbs. Calcium Caseinate ½ lb. Water 50 gals.	10	10	2.8
Lead Arsenate 1½ lbs. Molasses ½ gal. Water 50 gals.	10	9	4.1
Lead Arsenate 1½ lbs. Molasses ½ gal. Water 50 gals.	10	8	3.4
Lead Arsenate 1½ lbs. Water 50 gals.	10	8	7.8
Lead Arsenate 2 lbs. Water 50 gals.	10	8	4.4

Table 15.—Effect of Lead Arsenate Sprays, with and without Lime-Sulfur solution, on the Control of Plum Curculio Beetles on Apples. June 11-28, 1928.

Insecticide and Fungicide	Number of Curculios at Beginning	Number of Curculios Dead after 8 Days	Average Number of Punctures per Beetle In Apples when Experiment Closed
Lead Arsenate 1½ lbs. Calcium Caseinate ½ lb. Water 50 gals.	10	8	5.2
Lead Arsenate 2 lbs. Calcium Caseinate ½ lb. Water 50 gals.	10	10	2.8
Lead Arsenate 1½ lbs. Calcium Caseinate ½ lb. Lime-Sulfur Solution 1 gal. Water 50 gals.	10	7	4.5
Lead Arsenate 2 lbs. Calcium Caseinate ½ lb. Lime-Sulfur Solution 1 gal. Water 50 gals.	10	9	3.0

fruit would have been greater if the orchard had been planted to more susceptible varieties such as Duchess, Yellow Transparent, or Gravenstein.

The results of the 1926 orchard experiments, planned principally to determine the most effective time of application, are shown in Table 16. Other orchard spraying experiments, planned largely to compare materials, are referred to frequently in this bulletin but these are still incomplete in some details and are not reported in tabular form.

In the spraying experiments reported in Table 16, the applications were made as follows; Pink—May 19; Calyx—June 2; 7-day—June 9; 3-weeks—June 23.

The materials in all sprays were lime-sulfur solution, 1 gallon in 50 gallons of spray; calcium caseinate ½ pound in 50; and lead arsenate 1½ pounds in 50 except in Plat VI where 2 pounds of lead arsenate in each 50 gallons were used.

The spraying program in Plats II-A and II-B was identical, but the dropped apples were picked up during June and July in the former. Plat II-A had 1.02 per cent more clean fruit and showed a decrease of .29 in the average number of stings per stung apple, largely by the elimination of many fall feeding punctures. This benefit is small, but is all that should be ex-

Table 16.—Results of Orchard Spraying Experiments, North Littleton, Mass., 1926.

Plat	Treatment	Fruit	Number of Apples	Number of Stings	Av. No. of Stings per Stung Apple	Apples Uninjured **Per Cent**
I	None	Drops	4483	18003	4.42	**9.19**
		Harvest	166	867	5.35	**2.41**
		Total	**4649**	**18870**	**4.46**	**8.95**
II-A	All Sprays— Early Drops Picked Up	Drops	2613	345	1.50	**91.20**
		Harvest	1520	188	1.40	**91.18**
		Total	**4133**	**533**	**1.46**	**91.19**
II-B	All Sprays— Early Drops Not Picked Up	Drops	3058	486	1.83	**91.33**
		Harvest	549	98	1.44	**87.61**
		Total	**3607**	**584**	**1.75**	**90.17**
III	Pink Spray Omitted	Drops	3681	448	1.83	**92.52**
		Harvest	1999	190	1.45	**93.35**
		Total	**5580**	**638**	**1.59**	**92.99**
IV	7-day Spray Omitted	Drops	3102	589	1.68	**88.69**
		Harvest	1502	225	1.41	**89.35**
		Total	**4604**	**814**	**1.59**	**88.90**
V	3-weeks Spray Omitted	Drops	645	550	2.66	**67.91**
		Harvest	734	169	1.67	**86.24**
		Total	**1379**	**718**	**2.33**	**77.67**
VI	All Sprays— Lead Arsenate 2.50	Drops	230	53	2.30	**90.00**
		Harvest	1713*	141	1.29	**93.64**
		Total	**1943**	**194**	**1.47**	**93.21**

* Due to the small number of apples on the count trees in Plat VI, harvest fruit from other trees in addition to the count trees was examined and included in the record for the plat. Therefore, a comparison between the injury to dropped fruit and the harvest fruit in Plat VI is not significant.

pected, since the greatest effect of destroying infested "drops" becomes apparent the following season.

Arsenical Residue.

Under Massachusetts conditions, the amount of arsenic trioxide which remains on the fruit as spray residue at harvest is well below the legal tolerance of .01 grains per pound of fruit, following any of the recommended spray schedules. Analyses in 1927 showed that even where fish oil, a most persistent sticker, was used the residue on McIntosh contained only .0036 grains of arsenic trioxide, and on Baldwin .0035 grains, both about 1/3 of the amount tolerated.

Spray Schedule.

The following adaptation of the standard spray schedule, based on the results of the experiments herein reported as well as on many orchard observations and other reports, is recommended for combating the plum curculio in apples in Massachusetts under average conditions. Due consideration should be given to the abundance of the insect, any abnormal seasonal variation, and other factors peculiar to a specific orchard. A complete spray schedule for apples in Massachusetts is printed in Massachusetts Agricultural Experiment Station Bulletin 233, The Codling Moth in Massachusetts (1).

ADAPTATION OF THE STANDARD ORCHARD SPRAY SCHEDULE TO COMBAT PLUM CURCULIO

Application	When Applied	Materials	Remarks
Calyx Spray	Within 10 days after 90% of petals have fallen.	Lime-Sulfur Solution 2 Gals. Calcium Caseinate 1 lb. Lead Arsenate 4 lbs. Water 100 Gals.	Add 1 pint of nicotine sulfate if plant lice, red bug, or leaf hopper are present. 8 lbs. of dry lime-sulfur may be substituted for 2 gallons of lime-sulfur solution in all sprays.
7-day Spray (1st Curculio)	7 to 10 days after calyx spray, or when first apples become ½ inch in diameter.	Lead Arsenate 4 lbs. Fish Oil, or 1 pint Molasses 1 gal. Water 100 gals.	Add 2 gallons lime-sulfur solution to combat apple scab on McIntosh if necessary.
3-weeks Spray (2nd Curculio)	About 3 weeks after calyx spray.	Lime-Sulfur Solution 2 Gals. Calcium Caseinate 1 lb. Lead Arsenate 4 lbs. Water 100 Gals.	Add fish oil as in 7-day spray when curculio are especially abundant at this time.

Dusting

Dusting with modern equipment has not been thoroughly compared with spraying as a means of combating the plum curculio in this work. Several progressive fruit growers in the state have maintained excellent protection from insect pests including the plum curculio by intelligent dusting, but in these orchards this pest has never become thoroughly established.

In 1927 a severely infested orchard was dusted experimentally with a standard orchard dust applied with hand dusters of the knapsack type. Three applications at opportune times yielded only 18 per cent clean fruit at harvest, but this was a gain of 10.8 per cent over the untreated plat and there were about one-third less punctures per apple. Dust applications should be made at the times recommended for spraying, with an additional application midway between the 7-day and 3-weeks treatments whenever possible. The dust must be thoroughly applied from at least two sides of the tree, preferably in calm weather when it will settle slowly. Dusts containing 15 or 20 per cent lead arsenate are more effective than those containing less poison.

SUMMARY.

The plum curculio, a native of North America, is found throughout eastern and central United States and at present is the most injurious insect pest of apples in Massachusetts.

Plums are preferred as food but only slightly more than apples, and all stone and pomaceous fruits may be attacked.

Of the apple varieties, Duchess, Yellow Transparent and Gravenstein, which blossom early or develop rapidly after the petals fall, are more severely injured in the spring than late-developing sorts such as Northern Spy and McIntosh.

Beetles damage the fruit by making egg punctures, early feeding punctures and late feeding punctures in it, and the larvae tunnel through it. An egg puncture is distinguished by a characteristic crescent-shaped cut which develops into a fan-shaped russet scar. An early feeding puncture is round and usually forms a circular russet scar. Larvae eat the flesh of the apple, especially near the core, and cause the fruit to fall while small. The spherical cavities of late feeding punctures in mellow or nearly mature fruit do not heal, and are generally followed by decay.

The plum curculio passes through four stages of development: egg, larva or grub, pupa, and adult or beetle. Each female beetle lays about 175 eggs from which the larvae hatch in about seven days. Young larvae burrow out of sight in the fruit about two hours after hatching, and remain there approximately sixteen days. Pupal cells are made three inches or less beneath the surface of the soil, and the insect remains in them about thirty days as larva, pupa, and adult. About fifty-five days are necessary for the plum curculio to develop from egg to adult. The beetles live approximately a year, from August to August, and there is but one generation annually in Massachusetts.

In confinement the beetles made an average of 236 feeding punctures per pair, and feeding punctures constituted from 64 to 83 per cent of the total number of punctures.

The beetles choose leaves for hibernating cover in preference to hay and stones.

A pictorial diagram of the seasonal history of this insect in apples occurs on page 35. The first overwintering beetles appear when the blossom buds are showing pink, and the largest number enter the trees between June 10 and 30. The first eggs are laid about June 1, and the number deposited in-

creases steadily to a maximum between June 21 and 30. Oviposition ceases about August 1. Feeding by overwintering beetles begins and reaches the maximum about the same time as oviposition, but it continues in decreasing amounts until cold weather. Larvae leave the fruit first about June 30, in greatest number between July 10 and 20, and cease before September 1. Beetles emerge from the soil from late July to early October, reaching a maximum between August 6 and 20.

Sixty to seventy-five per cent of the plum curculio beetles die during the winter in Masachusetts.

Larvae and pupae may be killed by exposure to hot sun and by baking and packing of the soil surrounding the pupal cells.

A few birds and predatory insects eat the plum curculio, and one species of hymenopterous parasite has been reared from it, but none of these natural enemies decreases the abundance of this pest to a noticeable extent.

Many beetles may be killed by burning the leaves, brush, and woods in which they are spending the winter.

Picking up dropped apples between June 20 and July 20 and killing the larvae in them is the most effective cultural operation for combating the plum curculio in apples. The apples should be picked up not later than ten days after they fall and either buried with quicklime, boiled, burned, or fed to livestock. Sheep or hogs in the orchard help to control the pest by eating the infested apple "drops."

Cross cultivation close to the tree trunks with an extension disc harrow may kill many pupae if done between July 20 and August 1.

A ½ per cent solution of carbon disulfide emulsion applied to the soil at the rate of 3 pints per square foot killed 99.5 per cent of the plum curculio larvae and pupae in laboratory experiments.

With a normal crop of fruit, thorough spraying will give commercial control of the plum curculio when the number of insects averages less than 25 per tree. *Thoroughness* of application with adequate machinery in good repair is the most important factor in the spraying operation.

The calyx spray, the 7-day spray, and the 3-weeks spray are the most important for combating the plum curculio in apples. Of these, the 7-day or first curculio application is the most effective.

Powdered lead arsenate, 2 pounds in each 50 gallons of spray, is recommended in a spray schedule to combat the plum curculio. There is little danger of excessive arsenical residue following the recommended spray schedule.

The addition of stickers to the poison has consistently reduced the number of days necessary to kill the beetles as well as the number of punctures made in sprayed fruit. Fish oil at the rate of 4 liquid ounces to each pound of poison, regardless of the quantity of diluted spray, and molasses at the rate of 1 gallon in each 100 gallons of spray, have proved the most satisfactory stickers.

Lime-sulfur solution combined with lead arsenate slightly but not seriously decreases the effectiveness of the poison.

Dusting although not thoroughly compared, does not appear to be as effective as spraying for combating this insect.

LITERATURE CITED

1. Bourne, A. I. and Whitcomb, W. D. The Codling Moth in Massachusetts, Mass. Agr. Exp. Sta. Bul. 233, pp. 55-72, illus., 1927.

2. Butler, O. and Doran, W. L. Spray Solutions and the Control of Apple Scab, N. H. Agr. Exp. Sta. Tech. Bul. 36, 15 p., 1928.

3. Extension Services of New England States. The New England Seven, 9 p., illus., 1928.

4. Fulton, B. B. The Apple Curculio and Its Control by Hogs, Jour. Agr. Research, 36: 249-261, illus., 1928.

5. Garman, Philip. The Curculio Problem in Connecticut, Conn. (State) Agr. Exp. Sta. Bul. 275 (1925), 286-291, 1926.

6. Hood, C. E. Fish Oil, An Efficient Adhesive in Arsenate of Lead Sprays, U. S. Dept. Agr. Bul. 1439, 21 p. illus., 1926.

7. Leach, B. R. and Lipp, J. W. Control of Japanese Beetle Grubs—Part I, Treatment of Lawns, Penn. Dept. Agr. Gen. Bul. 440, 21 p., illus., 1927.

8. Leiby, R. W. and Gill, J. B. The Plum Curculio on Peaches in North Carolina—Its Life History and Control, The Bulletin. N. C. Dept. Agr., 23 p., illus., 1923.

9. Quaintance, A. L. and Jenne, E. L. The Plum Curculio, U. S. Dept. Agr., Bur. Ent. Bul. 103, 250 p., illus., 1912.

10. Snapp, O. I. and Alden, C. H. Dusting and Spraying Peach Trees after Harvest for Control of the Plum Curculio, U. S. Dept. Agr. Bul. 1205, 18 p., illus., 1924.

11. Snapp, O. I. Insects Attacking the Peach in the South and How to Control Them, U. S. Dept. Agr. Farmers' Bul. 1557, 42 p., illus., 1928.

Publication of this document approved by the Commission on Administration and Finance

5M-4-29 No. 5327

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 250 April, 1929

The Consumer Demand for Apples

By Lorian P. Jefferson

The purpose of production is the satisfaction of the requirements of consumers. In order to meet them efficiently, it is necessary to know the character and extent of the demand. This type of investigation has received comparatively little attention, but the importance of such information becomes increasingly evident. It was in the hope of benefiting both grower and dealer that this study was undertaken.

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AGRICULTURAL EXPERIMENT STATION
AMHERST, MASS.

THE CONSUMER DEMAND FOR APPLES

By Lorian P. Jefferson,

Assistant Research Professor of Agricultural Economics

Introduction

This study is undertaken in the firm belief that attention has been centered too much on methods and volume of production and too little upon the purposes of production. The importance of the consumer as a factor in the marketing of all products has been too much overlooked.

The purpose of the study is to determine with as great accuracy as possible the exact nature of the demand for apples. The facts here presented should be of use to both grower and dealer. The grower should profit by a knowledge of what the consuming public prefers. He can plan to meet this demand, and should get better return for his product if he offers to the dealer just what the consumer wants. The dealer, likewise, will be benefited because he can offer for sale what his customers wish to buy.

Four classes of material are presented in this report:

1. The first class of data relates to specific demand in Springfield. It was the intention to use this market as a typical community for the study of consumer demand, and insofar as information is at hand, this has been done. Records of receipts and outgoing shipments are, however, not available, nor is information as to prices of apples in Springfield complete for any period of years. Specific figures used are mostly estimates secured from growers, wholesalers and retailers.

In that portion of the study based upon this class of data, the consumer demand for apples is presented from the point of view of the producers, the wholesalers and the retailers.

2. The second type of information used in the study is the data derived from the records of the Nashoba Apple Packing Association, which the officials of the organization very kindly placed at the author's service. These records are of the greatest value because they deal with large volumes of the leading varieties, giving prices paid for the different grades and sizes of these varieties during four seasons. Upon these figures is based the discussion of the demand for apples as indicated by the prices received for them. Thus is added statistical evidence as to the character and weight of consumer demand.

3. The third class of material is derived from some 1400 questionnaires sent to housewives in Massachusetts, Connecticut and Rhode Island.[1] The material for Connecticut has not been published in any form. The data for Massachusetts have been summarized in Bulletin 231, Massachusetts Agricultural Experiment Station, and those for Rhode Island were discussed in Bulletin 203, Rhode Island Experiment Station; but in order to point

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[1] The schedules for Connecticut and Rhode Island were made available by the courtesy of Professor I. G. Davis, of Connecticut Agricultural College, and Dr. R. B. Corbett, of Rhode Island State College.

out differences in the character of demand in the three states, and to give the added weight of so large an amount of evidence, it has been deemed worth while to present the material as here shown.

Moreover, New England markets are not far apart and shipments of produce from one to another are not uncommon, so that facts concerning demand in neighboring markets may be of use to both growers and dealers.

4. The fourth class of material, likewise statistical in character, deals with wages, both actual and real, in relation to the prices and consumption of apples over a term of years. For the statistics of real wages the author acknowledges indebtedness to Professor Paul H. Douglass of the University of Chicago. Other wage statistics are taken from reports of the United States Department of Labor. The purpose in presenting this material is to show the relation, if any, between the consumer demand for apples and the volume of money the industrial classes may have to spend.

The Springfield Market

Springfield Trade Area

In general the trade area of Springfield is estimated by the Springfield Chamber of Commerce as extending about fourteen miles from the center of the city. This includes Holyoke, Chicopee, Chicopee Falls, West Springfield, Longmeadow, East Longmeadow, Ludlow, Indian Orchard and Agawam. For the purposes of this study, however, some adjustments must be made because of certain receipts of apples in this area throughout the weeks of the fall and early winter, which do not go to Springfield. The apples received in this trade area from cold storage and from other than the local producing sections are purchased through the Springfield and Holyoke wholesalers.

The population which may rightly be considered as a part of Springfield's apple consuming public numbers about 80,000 in addition to the population of the city proper, making a total of about 232,000.

As is true in the city of Springfield, so in these surrounding towns combining with the city to form this trade area, large quantities of apples are sold by the growers directly to the retailers. Some of the retailers in these towns report that they obtain all their apples from growers during the fall. Others buy considerable quantities from growers, although some of their supply is purchased from Springfield dealers throughout the entire season.

In these towns also there is more or less distribution of apples from grower to consumer; but this volume is uncertain and difficult to estimate. It is, however, reasonable to assume that at least as high a ratio exists here as in Springfield proper, where about one-tenth of a bushel per capita is estimated as distributed directly by growers to consumers. This adds about 8,000 bushels to the total volume for the trade area. Allowance must be made also for the volume supplied by growers to retailers, which has been estimated as the total supply for twelve weeks of the fall, or perhaps one-third of the apple season. This adds, conservatively, about 20,000 bushels to the total volume for the Springfield area. No estimate is attempted of the volume purchased at roadside stands, which doubtless amounts to a considerable quantity during the early fall.

Receipts

Apples are received in Springfield in carlots from outside New England —from New York, Virginia and other Southern apple areas, and the Northwest. They are also received from local growers in Massachusetts and Connecticut, who sell their fruit to wholesale houses, mostly on commission; from growers who sell to retailers or directly to consumers. The chain stores also do a large business which is not handled through these channels, as they maintain their own buyers and store their supply independently of the market agencies. There are also dealers who go out into the country and buy as a bargain offers, often taking the whole of a grower's crop, and usually buying "orchard run", just as the fruit comes from the tree, without sorting or grading. These men have no place of business, but sell from wagon or truck to anyone who will buy—consumer or retailer. Some years these men have occupied a vacant lot or store near the shopping district during a few weeks in the fall, but recently the lots so used have been occupied by permanent business, thus forcing these buyers elsewhere.

The total receipts for the Springfield trade area for which apples are supplied through the city market or from nearby growers may be stated as follows:

Table 1.—Methods of Sale and Estimated Volume of Apples Received in Springfield Trade Area.

Method of Sale	*Bushels*
Grower to consumer	31,000
Grower to retailer	50,000
By wholesalers	147,000
By chain stores	45,000
At farmers' market	3,000
Total	**276,000***

* These estimates are based upon reports from wholesalers, from retailers in Springfield and neighboring towns, and from growers who sell apples in the trade area.

Sales of apples by Springfield wholesalers to dealers outside this trade area are estimated at 53,000 bushels, leaving some 223,000 bushels for consumption in the Springfield trade area. This provides a per capita supply of .96 bushels, which is close to the estimated per capita consumption in the United States.

Methods of Distributing Apples

Apples are distributed in the Springfield trade area by wholesalers, by hucksters or jobbers who buy from the grower or the wholesaler and sell chiefly at the open air market,[2] by retailers and by growers. Considerable quantities of products are handled at this "farmers' market", as it is called, but for the most part the quality of the produce sold here is not of the best.

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[2] This market is a vacant lot in the wholesale district that is regularly occupied during the season by growers who sell here their own fruits and vegetables, and by buyers who purchase their supplies from grower or wholesaler as chance offers. Few hucksters sell from door to door.

The four chain store systems represented in the area also handle large volumes of apples, bought directly from the grower in New England and New York. These quantities, because they do not go through the ordinary channels of trade, have been sometimes overlooked in estimating the volume of products handled.

Demand and Price

The strongest proof of a consumer's preference for any product is the price he will pay for it in competition with other products. In the case of apples, the consumer's preference for a definite variety, grade or size is indicated by what he will pay for it in preference to other varieties or grades or sizes.

Through the courtesy of the officials of the Nashoba Apple Packing Association, access was given to the records of the organization for the four seasons, 1924-1927. These supply the net price to the grower for all apples sold through the Association during the period, a total of such volume as to make the figures fairly reliable. These figures are of value also because the costs of marketing are the same for all lots and all varieties, and because the method of marketing is the same throughout the period.

The records of the Nashoba Apple Packing Association have been studied to determine the preferences of consumers. The volumes of different varieties, grades and sizes of apples handled by the Association have been analyzed with reference to the prices paid for them.

Variety and Price

The relative preference for varieties is best shown by a comparison of the prices they bring in competition with each other. Following is a table which shows average net prices received by growers for different grades of each variety handled in each season.[3]

Table 2.—Average Prices to Growers, of Ten Varieties, 1924-1927.*
A Grade (per box)

Variety	*1924-25*	*1925-26*	*1926-27*	*1927-28*
Baldwin	$2.03	$1.71	$1.12	$2.24
Delicious	....	....	1.55	....
Gravenstein	1.93	2.25	1.23	2.52
Greening	....	....	1.14	1.46
McIntosh	2.32	2.17	2.26	2.57
Northern Spy	....	....	1.18	2.13
Oldenburg	....	....	2.15	....
Wagener	1.99	....	1.27	2.15
Wealthy	1.92	1.55	1.01	2.21
Williams	....	....	2.57	....

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[3] Of course it must be recognized that not all these varieties are on the market at the same time, the Williams, Oldenburg and Gravenstein being early varieties which obviously can not seriously affect the market for the Baldwin and other winter apples. The early varieties find their competitors rather among other fruits, such as peaches and pears.

B Grade (per box)

Baldwin	1.53	1.19	1.11	1.30
Delicious	....	....	1.08	....
Gravenstein	1.54	1.56	.88	2.12
Greening	....	....	.66	1.03
McIntosh	1.80	1.69	1.60	1.61
Northern Spy	....	....	.47	.39
Oldenburg	....	....	1.08	....
Wagener	1.64	....	.83	1.83
Wealthy	1.56	1.29	.69	1.20
Williams	....	....	1.95	....

* Average prices received by Nashoba Apple Packing Association.

The volume of different varieties varied greatly, the total volumes of some being too small to warrant conclusions. Obviously small volumes can not fairly represent the variety; nor is one season enough for consideration. In the study, therefore, statistics of the five leading varieties are generally used, lest injustice be done those of which small volumes have been packed.

It is evident that the McIntosh has been the general favorite during the four seasons, 1924-25 to 1927-28.

In order to determine the standing on the market of graded and ungraded fruit, statistics of volumes and prices for the different grades were compared. The figures supplied by the Nashoba Apple Packing Association again offer the best available information on prices of graded fruit.

Unclassified apples, also known as ungraded, are of two kinds,—one is the "tree run" crop, culls and ciders only being removed; the other is made up of those apples remaining after apples of B grade and better, with culls and ciders, have been removed. Obviously these two groups will usually differ greatly in quality, since the removal of all fruit suitable for B grade or better, leaves little of very desirable quality to be classed as "ungraded". The other kind of unclassified, "tree run", usually contains fruit which could be graded into A or B, and is therefore more desirable.

Since these are both sold as unclassified, no distinction being generally made on the market, it is difficult to make fair price comparisons. However, from individual records collected the following data have been compiled for two seasons, 1925-26 and 1926-27, showing variety, volume and price received.[4]

The preference for "tree run" fruit is evident in the prices received, which show a difference ranging as high as 67 cents a box.

It would be very desirable if some distinguishing name were found for the so-called "ungraded" remaining after B grade or better, and culls and ciders have been taken out. Perhaps "domestic", the name used by the Nashoba Apple Packing Association, is as suitable as any. The class here

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[4] These prices were obtained from growers in a study of variety performance, not yet complete. It must be explained that the volumes of Gravenstein and Wealthy were not as large as the volumes of Baldwin and McIntosh. It is not improbable that larger volumes from a larger number of orchards might change the results for any of the varieties. These are here presented, as the only data available, for what they may be worth. They probably indicate the general relationship.

Table 3.—Average Prices Received by Growers for Ungraded Apples, 1925 and 1926 Crops.

Variety	After Removing Graded Fruit, Culls and Ciders *per box*	After Removing Culls and Ciders Only *per box*
Baldwin	$ .48	$1.14
Gravenstein	.75	1.42
McIntosh	1.17	1.67
Wealthy	.88	1.04

called "tree run" (culls and ciders only being removed) might well be designated as ungraded or unclassified.

In order to determine with accuracy just how profitable grading may be, just how much more the consumer will pay for graded than for ungraded apples, it would be necessary to compare lots exactly the same in every particular—variety, volume, quality, color, etc., even including market conditions, one lot being sold graded and the other ungraded, culls and ciders being taken from both lots.

Obviously it is impossible to fulfill all these requirements. Data concerning such exactly comparable lots of apples are not available. The best figures at hand include no information as to these items in the case of tree run fruit. Prices of apples sold as tree run, culls and ciders out, are compared in Table 4 with prices of A and B grade apples.

Table 4.—Comparison of Average Prices of Graded and Ungraded (Tree Run) Apples, 1925 and 1926 Crops.*

Variety	A Grade *per box*	B Grade *per box*	Ungraded (Tree Run) *per box*
Baldwin	$1.41	$1.15	$1.16
Gravenstein	2.05	1.04	1.42
McIntosh	2.21	1.67	1.66
Wealthy	1.09	.80	1.04

* The prices of graded fruit are from the records of the Nashoba Apple Packing Association; those for ungraded are from schedules secured in the aforenamed study of variety performance, not yet completed.

These figures indicate that in general only A grade or Fancy apples of these varieties brought prices which warranted grading. Only as B grade apples are considered as a by-product of better grades did the grower find it worth while to pack them. The market is, insofar as these figures may be taken as fairly typical, rather indifferent to the grading of Wealthy apples, the ungraded lots having brought nearly as high a price as A grade and 30 per cent above the price for B grade.

The preference for A grade as indicated by these prices is more apparent in the case of Gravenstein than in that of any other variety included in the table.

It is evident that most consumers definitely prefer A grade apples of the leading varieties. This preference is apparent in Table 5 in which are presented the average prices by grades for each of the five varieties in the seasons for which figures are available.

Table 5.—Average Prices by Grades, 1924-1927.

Variety	A Grade	B Grade	Premium for A Grade
	per box	*per box*	*per box*
Baldwin	$1.45	$1.24	$ .21
Gravenstein	1.52	1.12	.40
McIntosh	2.35	1.69	.66
Wagener	1.80	1.50	.30
Wealthy	1.28	1.05	.23
Average	**1.80**	**1.41**	**.39**

The preference for A grade fruit varies in degree from season to season. The McIntosh shows a higher and more regularly increasing premium than any other variety, as exhibited in Table 6. The increasing spread between A and B grade of this variety has been due not only to the increase in the price of A grade, but to a decrease in the price of B grade fruit as well.

In the case of the Baldwin, the premium for A grade fruit varies greatly from year to year. In the two seasons 1924-25 and 1925-26 this premium averaged about 6 cents a box, while in the season of 1927-28, the average A grade brought 94 cents a box more than B grade.

Table 6.—Premium for A Grade McIntosh, 1924-1927.

Season	A Grade	B Grade	Premium for A Grade
	per box	*per box*	*per box*
1924-25	$2.32	$1.80	$ .52
1925-26	2.17	1.69	.48
1926-27	2.26	1.60	.66
1927-28	2.57	1.61	.96
Average	**2.35**	**1.69**	**.66**

Preferences as to Size

An examination of the prices received by the Nashoba Association shows that the demand as to size varies with the variety. Only the Baldwin, Gravenstein, McIntosh, Wagener and Wealthy were handled in sufficient quantities to warrant conclusions as to sizes preferred. However, in Table 7 are included all varieties packed during two or more of the four seasons.

It is evident that Baldwins and Greenings, insofar as these statistics indicate, are preferred in the large sizes, the price increasing with the increase in size. While the Wealthy shows the same trend, the difference between prices for the various sizes is comparatively small, and apparently indicates that consumers care little about the size of this variety.

The McIntosh, Northern Spy and Wagener returned the highest prices for size 2¾ inches, the larger sizes bringing a lower price in each variety.[5]

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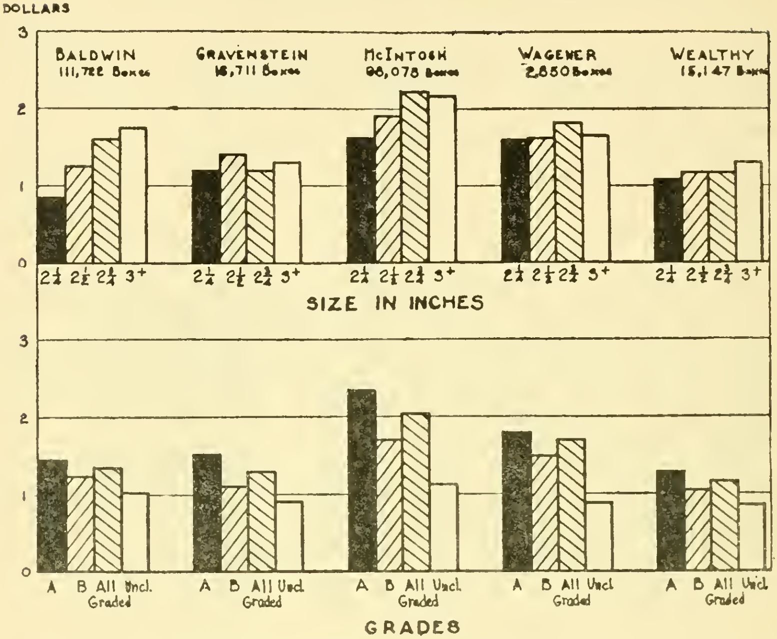
[5] Kroeck, J., Factors Affecting the Price of McIntosh. (Massachusetts Department of Agriculture) found that the prices received for the 190 boxes examined in the study showed a preference for 3 inch apples. However, the period covered was short and the volume comparatively small, but there may be a growing preference for larger sizes of this variety.

Chart I. Prices of Apples by Varieties, Sizes and Grades, 1924-1927.



From records of the Nashoba Apple Packing Association. The Prices for Baldwin and Gravenstein are for three seasons only.

While the average price for Gravenstein 2½ inches in size was higher than for any other size, a range of but 20 cents between the highest and the lowest prices indicates that size is not an important factor with this variety.

The prices by variety and size for the four seasons show irregularities which can be partly accounted for by export sales. But an examination of the figures shows that the quality of the fruit must sometimes have been a factor in determining the price. No measure of quality other than that apparent in the grade has been established.

Table 7.—Average Prices by Variety and Size, 1924-1927.

Variety	2¼ inch *per box*	2½ inch *per box*	2¾ inch *per box*	3 inches and over *per box*
Baldwin	$ .84	$1.25	$1.62	$1.76
Gravenstein	1.20	1.40	1.20	1.31
Greening	.45	.69	.96	1.34
McIntosh	1.62	1.91	2.23	2.16
Northern Spy	1.09	.98	1.49	1.27
Wagener	1.59	1.62	1.80	1.64
Wealthy	1.07	1.17	1.18	1.29

Queries among dealers and buyers for eating houses in Springfield indicate that the preferences as to size in that market are practically the same as are shown by Nashoba prices. The demand is apparently tending toward the larger sizes.

Housewives' Preferences

From 1400 questionnaires answered by approximately 600 housewives in Massachusetts, 600 in Connecticut and 200 in Rhode Island, some interesting information as to buying habits and preferences of consumers of apples has been gathered.

One question pertained to the sources from which apples are purchased. While volumes purchased from the different sources are not known, it was learned that practically one-fourth of the households from which reports were secured buy all or part of their supply of apples directly from the grower. As might be expected, purchases from growers are more common in Massachusetts and Connecticut than in Rhode Island, where there is less opportunity for such purchases, population being more concentrated and orchards proportionally fewer. One-fourth also buy from the general markets in their communities; 16 per cent buy more or less from chain stores; and 15 per cent buy some fruit from fruit stands, although the number of those who name the fruit stand as first choice of place to buy is small; 12 per cent patronize roadside stands and 6 per cent buy from peddlers who sell from house to house.

A tabulation of the sources from which consumers of the three states buy apples is given below.

Table 8.—Sources of Purchases.

	Choices						Total Times
Sources	First	Second	Third	Fourth	Fifth	Sixth*	Named
Grower	264	54	35	15	16	14	**398**
General Store	152	116	45	25	10	6	**354**
Fruit Stand	69	73	66	33	17	1	**259**
Chain Store	56	73	46	35	34	6	**250**
Roadside Market	21	63	44	29	31	11	**199**
Huckster*	20	25	11	16	11	12	**95**
Total	**582**	**404**	**247**	**153**	**119**	**50**	**1,555**

* In Connecticut only.

Varieties Preferred

The variety preferences differ somewhat in the three states. Connecticut gives first place to the Baldwin as an eating apple, this variety having 166 votes, while the McIntosh—easily first in the group of states—receives but 149 votes for first place in Connecticut. The Gravenstein, which is popular in its season in Massachusetts, being mentioned as a desirable eating apple 52 times, is mentioned only 5 times in Connecticut where nobody names it as first choice.

It is evident that, in the whole section, more people prefer the McIntosh for eating raw than any other variety. Of 1120 first choices of eating apples, 43 per cent are for the McIntosh. Of 3887 choices for all uses, 19 per cent favor this variety, 17 per cent naming it as a favorite eating apple, while 2 per cent like it for cooking, only the Baldwin and the Greening ranking higher for this purpose.

The Baldwin is the favorite cooking apple, 15 per cent giving it first place and 19 per cent naming it as first, second or third choice. Seven per cent name the Greening as their favorite cooking apple, most of this group being residents of Connecticut and Rhode Island, this variety being much less favored in Massachusetts markets. The following tabulation (Table 9) presents the rating of the varieties named the most times by these 1400 consumers.

Table 9.—Variety Preferences, by States

	CHOICES FOR EATING RAW				CHOICES FOR COOKING				**Total Times Named**
Variety	First	Second	Third	**Total**	First	Second	Third	**Total**	
Baldwin									
Connecticut	166	56	31	253	185	46	10	241	494
Massachusetts	90	88	30	208	269	47	5	321	529
Rhode Island	50	36	25	111	135	52	6	193	304
Total	**306**	**180**	**86**	**572**	**589**	**145**	**21**	**755**	**1,327**
McIntosh									
Connecticut	149	45	15	209	19	11	6	36	245
Massachusetts	241	57	13	311	12	12	2	26	337
Rhode Island	89	30	9	128	2	3	4	9	137
Total	479	132	37	648	33	26	12	71	719
Greening									
Connecticut	16	20	14	50	137	53	16	206	256
Massachusetts	4	4	7	15	45	44	11	100	115
Rhode Island	11	10	6	27	101	74	5	180	270
Total	31	34	27	92	283	171	32	486	578
Russet									
Connecticut	30	36	24	90	21	8	4	33	123
Massachusetts	10	27	24	61	3	2	0	5	66
Rhode Island	8	4	4	16	1	1	3	5	21
Total	48	67	53	167	25	11	7	43	210
Gravenstein									
Connecticut	0	2	3	5	1	4	0	5	10
Massachusetts	10	18	24	52	9	13	2	24	76
Rhode Island	7	5	5	17	5	5	3	13	30
Total	17	25	32	74	15	22	5	42	116

Some 70 other varieties are mentioned varying numbers of times, but none is named often enough to indicate commercial importance. Twenty of these varieties are regarded as suitable for eating only, while 12 are considered only as cooking apples; 29 are named but once for any use, and 23 are not the first choice of anyone for either purpose.

Recognition of Varieties

The Baldwin can be identified by more New England consumers than any other apple of 87 varieties named. The second best known is the McIntosh, but only 7 can identify this variety for every 10 who know the Baldwin; and only 6 can identify the Greening or the Russet for each 10 who can identify the Baldwin. Other varieties are familiar to smaller numbers, and 40 of the 87 varieties are known to but one person each; 13 varieties can be identified by 2 persons each; 73 varieties are familiar to fewer than 10 persons each.

Hardly 30 per cent of those reporting indicate their ability to tell

Eastern from Western apples. Of those who can, 54 per cent must eat the apple in order to make identification complete, as they tell it by the flavor. Fifteen per cent profess to be able to tell Western apples by their size, obviously a very questionable method. Nearly the same number say they identify them by the color. Only one person is able to identify them by the variety, and only one indicates that she makes inquiry as to the source from which they come.

Factors That Influence Buying

The qualities which appeal to the consumer and influence her buying are chiefly the flavor, appearance, condition, cooking quality, juiciness and size. One in four considers the flavor of the apples; 19 per cent are influenced by the condition of the fruit, and 7 per cent more by the cooking quality; appearance is a factor in the purchase of 11 per cent; juiciness and size each influences 9 per cent of the consumers.

More than half the housewives reporting, 54 per cent, stated a preference for apples of uniform size.

The price is named as a factor by 7 per cent and healthfulness by 4 per cent, although both are probably considered by many of those reporting, who neglected to mention them.

Color is named by only 4 per cent as a determining factor. although both wholesalers and retailers declare that the demand is almost entirely for red apples. Only 2½ per cent say they buy by the variety, and still fewer state that they consider when buying the use to be made of the apples bought. It is evident, however, that the average housewife recognizes the general distinctions between eating and cooking apples. Two report that they buy by brand.

Regularity of Serving

The 418 housewives who report serving apples on their tables, in the summer, serve them on an average of 3.6 times weekly. In the fall, 471 families find apples in some form on their tables 5 times a week. In the winter the rate of serving falls back to about the same as in the summer, 493 housewives in this season serving apples an average of 3.7 times a week. The average for the year is 4.7 times, the most common number of times reported being 2 to 3.

Who Buys for the Family?

The housewife buys the apples in more than half the households reporting, just as she buys most other commodities for the home. The man of the family buys them in 30 per cent of the homes reporting and the responsibility is divided in 9 per cent.

The unit quantity of apples purchased by the consumer seems to be decreasing in size, customers now usually buying by the peck or by the pound, whereas their grandparents bought by the bushel or the barrel. The reasons for this are changes in living conditions, such as a tendency to buy all commodities in smaller quantities and more frequently; the rise of the neighborhood grocery store, making it easier to "go to market"; the development of super-heated apartment houses with limited storage space, and that too often not suitable for perishables. Better storage facilities outside the home make it easy for dealers to provide the public with good fruit throughout the year, and the housewife is now able to order apples as she needs them.

Consumption of Apples

Certain factors which undoubtedly have considerable influence on the demand for any commodity must not be overlooked, even though they may not lend themselves to exact measurement.

We are accustomed to take account of the influence which the demand for a product has on the price it will bring; but we less often consider the influence which the price of a product has upon the demand for it. Not only the total demand but the character of the demand may be influenced by the price. The housewife who goes to the market to buy apples may find that the A grade fruit, which she prefers, is priced so high that she can not afford it. She may instead accept B grade apples at a price within her means; she may substitute some other fruit for the apples she meant to buy; or she may decide that her purse does not allow the purchase of any fruit whatever. The effective demand of this consumer has been very definitely affected by the price.

Obviously the volume of any product sold in any market varies with the available supply. More will normally be consumed when the supply is large and the price relatively low. The supply, likewise, may affect demand unfavorably as well as favorably. The housewife whose purse is not too rigidly limited, frequently buys a product because it is not common, to get a change in diet; or conversely, she may turn away from one which has been on the market in abundance, regardless of the fact that the price is attractive. She has grown weary of it.

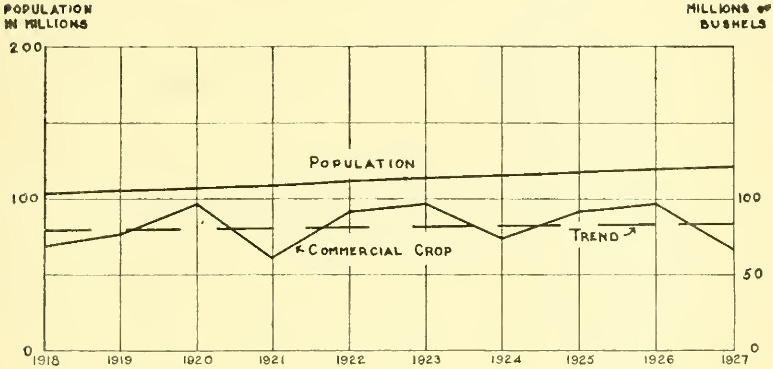
Unemployment, limiting as it does the purchasing power of the group out of work, has marked influence on the demand for most products. The unemployment which has been prevalent in Great Britain since the World War, for example, has affected the demand for practically all products. The buying power of large groups has been materially reduced, and the demand for nearly all commodities has been correspondingly less.

Advertising, well-directed, has its effect on the demand for the product advertised. A notable example of the results of advertising is the case of citrus fruit, the demand for which has been greatly increased since a systematic campaign of advertising has been carried on by the growers. It is, however, impossible to say that the increased demand is entirely due to advertising. Such factors as more intelligent distribution and improved pack and quality of the fruit, even if they can not be accurately measured, must have their influence on the volume and character of the demand.

Trend of Consumption

The complaint is frequently heard among dealers and growers that "people aren't eating as many apples as they did", and that consumption of apples is declining. In order to determine the truth of the statement, statistics of population and commercial crops are compared in Chart II. It is apparent that during the seasons from 1918 to 1927 the commercial crop, exports deducted, has steadily increased. It is equally evident that

Chart II. Population and Commercial Apple Crop of the United States, 1918-1927.



The increasing volume of the commercial crop is due not only to a greater number of bearing trees, but to better methods of growing. An increasing proportion of our total production is salable. Exports have been deducted.

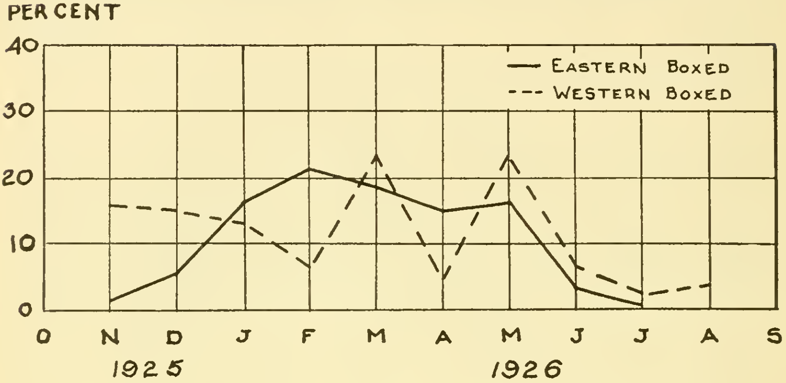
the increase in population during the decade has been more rapid than that of the commercial crop. This indicates, of course, that per capita consumption in the United States is actually declining. The trend of this decline is pictured in Chart VI, which shows the average per capita consumption for the ten years 1918 to 1927.

The Influence of Storage

Improved storage facilities have made it possible to have apples on the market throughout the year. Consumption has been steadied and spread out over the twelve months, and even the more delicate varieties are made available to consumers over a much longer period than formerly. The McIntosh, a few years ago considered a fall apple only, is now put into cold storage and its season thereby lengthened by several months. During the last few seasons, the best prices for McIntosh have been secured late in the season.

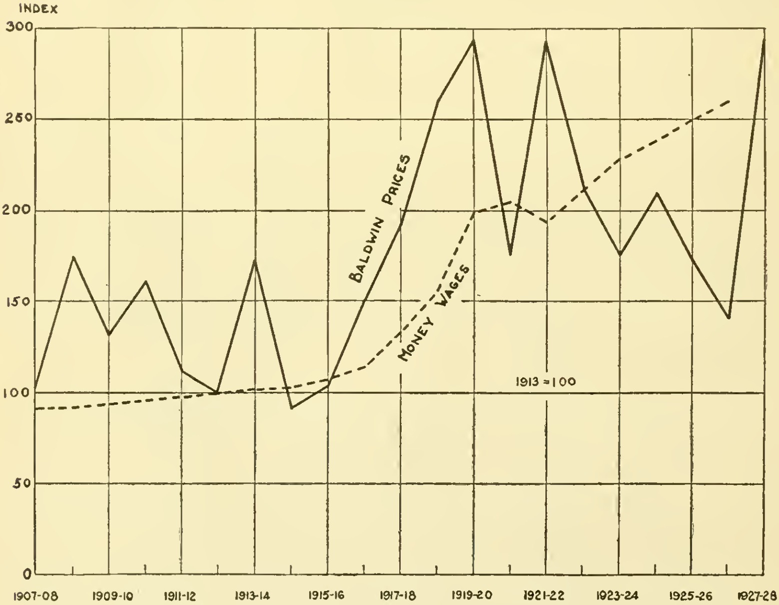
The rate of movement of any product out of storage depends largely upon the demand for it. Chart III shows the rate at which apples moved from storage in Boston in 1925-26, probably a fairly representative season. The movement of both Eastern and Western boxed apples is shown, and indicates that Eastern apples are in more steady demand during the season than are Western apples. As shown by this chart, withdrawals from storage might seem to indicate that the demand for Western apples in the fall is keener than that for Eastern fruit, whereas New England apples are actually in quite steady demand throughout the season. In the fall months this demand is met by supplies of fresh fruit which has been

Chart III. Rate of Movement of Apples from Storage in Boston, 1925-26.



kept in farm storages and does not appear in records of cold storage holdings. During the winter and spring, the movement from storage doubtless represents the demand with considerable accuracy.

Chart IV. Index of Baldwin Prices at Boston and Index of Industrial Money Wages per Hour, 1907-08 to 1927-28.
1913=100



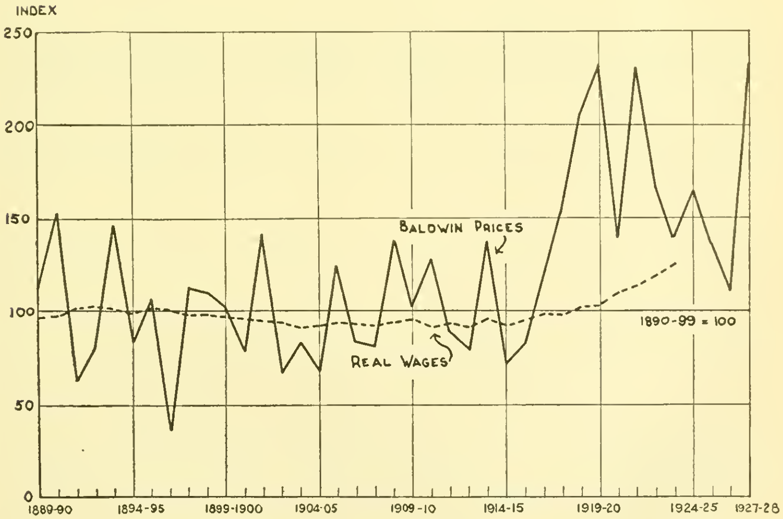
The prices of Baldwins in Boston were secured by the United States Department of Agriculture, and the wages from records of the United States Department of Labor.

Influence of Wages

Any consideration of factors affecting consumption must obviously include the question of wages, from which so large a part of our population derives its income. Wages are classed as the actual money wages received, and "real wages", which refers to the purchasing power of the money wage. It is evident that "real" wages are of more importance than are money wages, since "real" wages determine the volume and variety of goods the worker may obtain with his money. A comparative study of the index of all industrial wages in the United States with the index of wholesale prices of Baldwin apples on the Boston market shows practically no correlation between the two. It is evident that the money wage does not determine the demand for Baldwin apples, at least. Baldwin prices are used because they are to be had for a longer period than any other variety, and because Baldwins have been popular longer than any other variety. (Chart IV)

A similar comparison of the Baldwin prices and real wages in manufacturing industries in Massachusetts reveals little beyond the fact that the trend of the prices follows in a general way the line of real wages during most of the period. The last few years, however, show no correlation whatever. (Chart V) Nor is the relation between per capita consumption of apples and real wages more definite than that between

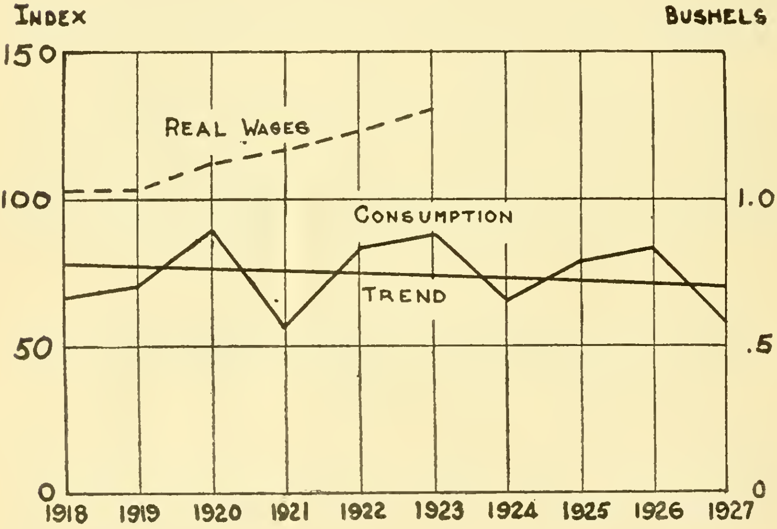
Chart V. Index of Baldwin Prices at Boston and Index of Real Wages in Manufacturing Industries of Massachusetts, 1889-90 to 1923-24.
1890-99=100



The statistics of real wages here used were prepared by Professor Paul H. Douglass of the University of Chicago. Although these are not available to date, it is doubtful if any closer correlation between the two lines would be shown in the later years than is evident to 1923.

wages and prices. (Chart VI). While it is true that the trend of total consumption of apples follows more closely the upward trend of real wages, per capita consumption is more fairly representative for comparison with these wage data. This lack of correlation between apple prices, per capita consumption and wages may be taken to indicate that apples, like certain other products, have become such a staple article of diet that apple consumption is little affected by the rise or fall of money wages or by the purchasing power of wages.

Chart VI. Per Capita Consumption of Apples, with Trend, and Index of Real Wages, 1918-1923.



Per capita consumption is calculated on the basis of the commercial crop from which the volume exported is deducted. This does not include farm consumption, for which no data are available.

Conclusions

1. It is evident that in the three southern states of New England the Baldwin is the favorite apple for cooking and the McIntosh for eating raw. These varieties can likewise be indentified by more consumers than can any other varieties.

2. The prices over four seasons show the McIntosh to be the favorite apple in the Boston market.

3. Less than one-third of the consumers reporting say that they can tell the Western from the Eastern apples, and more than half of those who can distinguish between them must eat the apple in order to make complete identification.

4. Flavor seems from consumers' reports to be the chief factor influencing the purchase of apples, although dealers report that color is very important, most customers desiring only red apples.

5. In the average household apples are served two or three times weekly, but there are many homes in which they are served more frequently.

6. Storage holdings of apples are largest in December, and movement out of storage is greatest in January, February and March, tending to spread the consumption over a longer period than formerly. Indeed, apples are now on the market twelve months of the year.

7. Prices received for the different grades show that consumers in general prefer A grade apples to B grade, although prices seem to indicate that in general consumers care little whether the early varieties are graded or not.

8. Two different classes of apples are now grouped together as "ungraded". There is need of distinguishing names for them in order to avoid confusion on the market. The term "ungraded" should be reserved for tree run fruit from which culls and ciders only have been removed. The other class—apples remaining when B grade and better, culls and ciders have been removed—may well be called C grade or "domestic", or some similar term.

9. The generally preferred sizes are 2¾ to 3 inches as indicated by the prices paid for them. More than half the consumers reporting prefer apples uniform in size.

10. The per capita consumption of apples in the United States is less than one bushel, and while the total consumption is increasing, this increase is not keeping pace with the increase in population. This indicates that the per capita consumption is gradually declining.

11. No correlation has been established between wages, either nominal or real, and the price of apples, nor between real wages and per capita consumption, this lack of correlation indicating that the consumption of apples does not depend on wages nor the purchasing power of wages.

Publication of this document approved by
the Commission on Administration and Finance.

5M-5-'29. No. 5728

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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 251 May, 1929

Causes of Differences in Poultry Profits

By R. L. Mighell and F. H. Branch

Records based on experience in poultry farming show wide differences in financial returns. It is assumed that these differences can be attributed to certain specific practices and conditions which may be subject to control or modification. This study was undertaken to determine the extent to which the various factors and conditions operated and were effective in influencing profit in the industry.

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AGRICULTURAL EXPERIMENT STATION

AMHERST, MASS.

Summary

1. Records from 144 Massachusetts poultrymen in 1926 and 134 in 1927 were the basis for this study of poultry profits.

2. Labor return per bird increased about 35 cents for each increase of one dozen eggs in the average production per bird. Average egg production per bird was the most important factor influencing profits per bird.

3. Labor return per bird increased 28 cents in 1926 and 35 cents in 1927 for each increase of one dollar in receipts other than from market eggs. Such receipts included those from hatching eggs, baby chicks, broilers, roasters, and so forth. These supplementary lines contribute to profitable poultry keeping.

4. When the number of birds in the flock was reduced after November 1 so that the plant was operating below full capacity, labor return per bird decreased about 36 cents with each ten per cent reduction in number of birds.

5. A five cent difference in average price received for eggs was related to a difference in labor return per bird of 19 cents in 1926 and 33 cents in 1927.

6. Fall egg production increased labor return per bird through its relation to average price received for eggs and annual egg production per bird.

CAUSES OF DIFFERENCES IN POULTRY PROFITS

By R. L. Mighell, Assistant Research Professor, and

F. H. Branch, Extension Specialist,

Department of Farm Management.[1]

Purpose and Timeliness of the Study

Expanding production, increasing emphasis on high quality products, and other changes in the economic situation lend timeliness to an analysis of the factors affecting profits from poultry in Massachusetts. With the individual poultryman, the future outlook raises such questions as: What can I do to offset possible lower prices of eggs and poultry? What changes in organization and operation should I make? Should I keep more hens? Should I produce more eggs in the fall months? The purpose of this bulletin is to help answer these and related questions by determining as nearly as possible on a dollar and cents basis just how much influence certain factors had on profits from poultry on Massachusetts farms in 1926 and 1927.

Basis for the Conclusions

The data upon which this study is based were supplied by poultrymen who participated in a cooperative poultry account project which has been conducted by the Extension Specialist in Farm Management. The purpose of this project has been to improve the accounting methods of poultrymen and to collect information to be used in the analysis of the poultry farm business. The data represent poultry production under actual farm conditions. Records were kept by each cooperating poultryman in a standard poultry account book. Monthly reports were sent to the Farm Management Department of the Agricultural College, where the tabulations, summaries, and final analyses were prepared. The poultrymen were visited once or twice during the year by the Extension Specialist in Farm Management.

The poultry account year began November 1 and ended October 31. The years for which complete records are available ended October 31, 1926, and October 31, 1927. The geographical distribution of the records analyzed in this study each year is indicated in Table 1.

Variations in Poultry Profits

Farm records nearly always show wide variations in returns from farm to farm. This is true in this instance, as shown in Tables 2 and 3. Labor return per flock and per bird is taken as a measure of earnings. Labor return is the amount of money left to pay labor (including that of the poultryman and his family) after all other expenses including interest on investment have been met. Credit is allowed for poultry products used on the farm. Labor return per bird is obtained by dividing labor return per flock by the number of birds at the beginning of the account year.

---

[1] Acknowledgment is due to Miss Marian Brown who had direct charge of the clerical work in connection with the analysis of the records.

This study aims to arrive at the reasons for this wide range in returns to poultrymen by comparing differences in certain factors found with the differences in labor returns.

Table 1. Distribution by Counties of Poultry Records Analyzed in the Study, for the Two Years 1926-1927.

County	Number of Records Analyzed	
	1926	**1927**
Barnstable	18	22
Berkshire	16	7
Bristol	15	10
Essex	—	13
Franklin	27	15
Hampden	7	9
Hampshire	20	16
Middlesex	18	14
Norfolk	—	5
Plymouth	9	10
Worcester	14	13
Total	**144**	**134**

Table 2. Poultry Flocks Classified According to Labor Return per Flock.

Labor Return per Flock	Number of Flocks Studied	
Dollars	**1926**	**1927**
-250— 0	4	4
0— 249	29	24
250— 499	28	23
500— 749	16	21
750— 999	13	12
1000—1249	10	8
1250—1499	5	9
1500—1749	6	9
1750—1999	8	3
2000—2249	5	2
2250—2499	2	4
2500—2749	4	2
2750—2999	1	1
3000 and over	13	13
Total	**144**	**134**

Possible Causes of Differences in Earnings

Many causes are constantly operating to affect the labor return from the poultry enterprise. Some of these causes are largely technical and include such items as proper feeding, disease control, and the careful selection of breeding stock. Other causes are economic in nature. They include, for example, changing prices of product and feed, the most profitable size of flock, and the relationship of poultry to other parts of the

Table 3. Poultry Flocks Classified According to Labor Return per Bird.

Labor Return per Bird *Dollars*	Number of Flocks Studied 1926	 1927
-1.00— 0.00	4	3
0.00— .99	13	10
1.00— 1.99	24	38
2.00— 2.99	40	39
3.00— 3.99	24	18
4.00— 4.99	18	14
5.00— 5.99	9	4
6.00— 6.99	10	2
7.00— 7.99	2	2
8.00— 8.99	0	2
9.00— 9.99	0	0
10.00—10.99	0	0
11.00—11.99	0	2
Total	**144**	**134**

farm business. The individual poultryman cannot change everything, but he may have the opportunity of adjusting those factors which can be controlled to offset adverse changes in others.

It will be understood that not all of the causes of variation in labor return have been included in this study. Some factors, such as daily management of the flock, handling of disease and sanitation problems, and other practices are not easily measured by simple flock records. Still other factors were not available in the records in enough detail to be of value. The final analysis was therefore limited to a study of the effect of the following factors on labor return per bird:

1. Annual egg production per bird; sum of the monthly averages for each flock.
2. Diversity of enterprise; credits from all sources except market eggs, expressed in dollars per bird.
3. Index of change in flock size; percentage that the average number of birds is of the initial number.
4. Price of eggs; sum of the monthly prices for each flock, divided by 12.
5. Fall egg production in the four months, September through December, expressed as a percentage of the total production for the year.

Most of the flocks studied were composed of Rhode Island Reds, some were Leghorns, and a few were other breeds. Since breed differences are largely reflected through the factors just enumerated, breed was not included as a factor in the study.

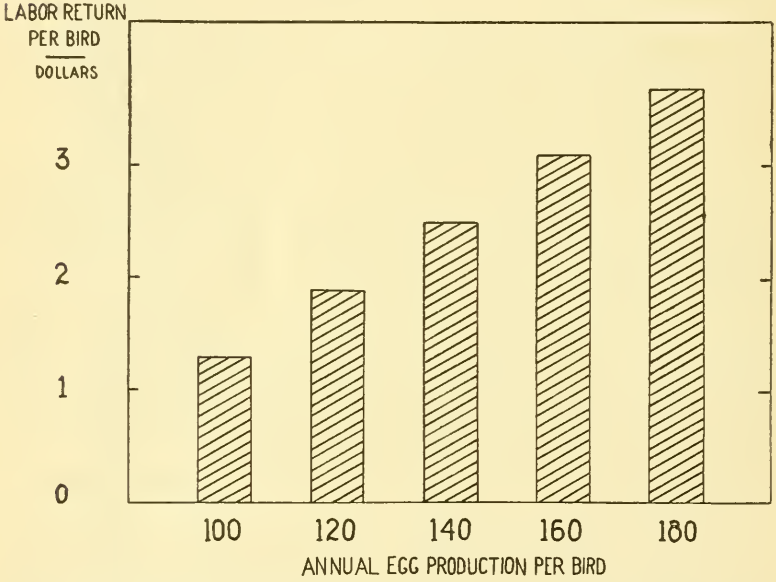
Effect of Individual Factors on Labor Return per Bird

The results of the analysis are expressed in terms of the effect of each factor on labor return per bird. This was found preferable to measuring the effect on labor return from the flock because differences in size of flock overshadowed the other factors when placed on that basis.

Since a preliminary analysis showed no measurable relationship between size of flock and labor return per bird, size of flock was not further considered among the factors affecting labor return per bird. So far as the flocks in this study were concerned, the large flocks made about the same labor returns per bird as the small ones. However, the poultrymen with the large flocks had to hire more labor, so that the labor returns to the poultrymen themselves were reduced by the amounts paid out in cash for hired labor.

Further discussion of the relative influence of each factor studied is given in the latter part of this bulletin under the explanation of the method of analysis used.

Figure 1.—Net Relation between Annual Egg Production per Bird and Labor Return per Bird, 1927.



The height of the bars represents the average trend of the relationship. Each additional 20 eggs was related to an average increase of 60 cents in labor return per bird.

Annual Egg Production per Bird

The average relation between egg production per bird and labor return per bird was found to be as shown in Table 4 and Figure 1. On the average each additional twenty eggs in production per bird was accompanied by an increase of 58 cents in labor return per bird in 1926, and an increase of 60 cents in 1927. This is about 35 cents and 36 cents average return for each additional dozen eggs laid.

The rather wide differences in average egg production per bird are shown in Table 5. The extreme variation is from about 70 to 230 eggs per bird. Many poultrymen can well afford to spend considerable effort and thought on increasing their average egg production. Those who are interested in comparing their own production records with others can use Table 5 for that purpose.

Table 4. Net Differences in Labor Return Associated with Differences in Annual Egg Production per Bird*

Annual Egg Production per Bird	Labor Return per Bird 1926 Dollars	Labor Return per Bird 1927 Dollars
80	1.00	.69
100	1.58	1.29
120	2.16	1.89
140	2.74	2.49
160	3.32	3.09
180	3.90	3.69

* The data shown in Table 4 and Figure 1 are not simple group averages but are smoothed averages or "regressions" obtained by fitting straight lines according to the method of multiple correlation. They represent the average trend of the relationship while holding constant the other factors studied. Any one of the individual records might fall above or below a line drawn parallel with the tops of the bars in Figure 1, but the line would represent the average tendency.

Table 5. Poultry Flocks Classified According to Annual Egg Production per Bird.

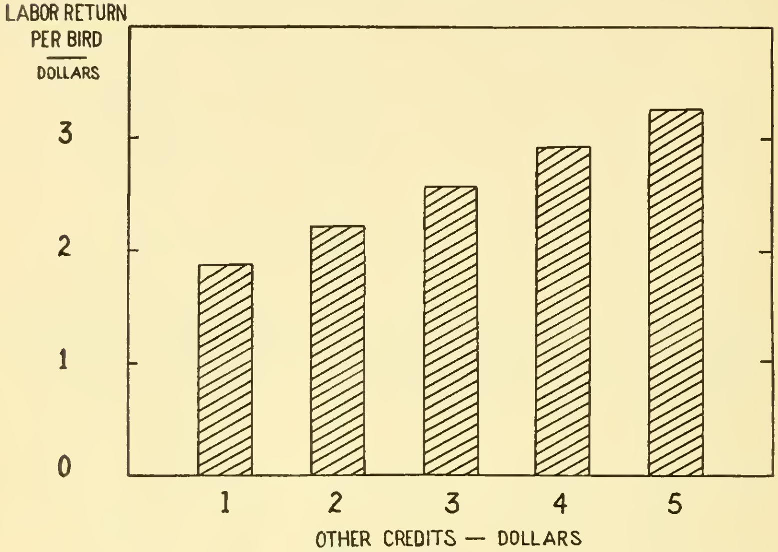
Annual Egg Production per bird	Number of Flocks Studied 1926	Number of Flocks Studied 1927
60— 79	1	1
80— 99	6	5
100—119	20	10
120—139	34	28
140—159	40	42
160—179	31	32
180—199	9	11
200—219	3	3
220—239	0	2
Total	**144**	**134**

Other Credits Than Market Eggs

The average relation found between other credits than market eggs per bird and labor return per bird is given in Table 6 and shown graphically in Figure 2. Other credits include receipts from hatching eggs and chicks, broilers, roasters, and so forth, as well as credits for products used at home and inventory changes. On the average, in 1926 an increase of one dollar in other credits than market eggs per bird was associated with an increase of 28 cents in labor return per bird, and in 1927 by an increase of 35 cents. The difference between one dollar and 28 or 35 cents can be regarded as approximating the various expenses necessary in the production of the additional dollar's worth of other credits.

The relative merits of the various sources of other credits than market eggs is an important field for study. Some poultrymen got increased returns from specializing in hatching eggs and baby chicks; others in pullets and breeding stsock; still others made good returns from broilers and roasters. The location, available capital and equipment, and the personal training and ability of the individual farmer frequently determine the wisdom of specializing in a particular line.

Figure 2.—Net Relation between Other Credits than Market Eggs and Labor Return per Bird, 1927.



The height of the bars represents the average trend of the relationship. Each additional dollar of other credits per bird was related to 35 cents increase in labor return per bird.

Table 6. Net Differences in Labor Return per Bird Associated with Differences in Other Credits than Market Eggs per Bird.*

Other Credits than Market Eggs per Bird	Labor Return per Bird 1926	1927
Dollars	*Dollars*	*Dollars*
2	2.56	2.22
4	3.12	2.92
6	3.68	3.61
8	4.25	4.30
10	4.81	5.00

*With other factors studied held constant at their average values. (See footnote, Table 4, p. 79.)

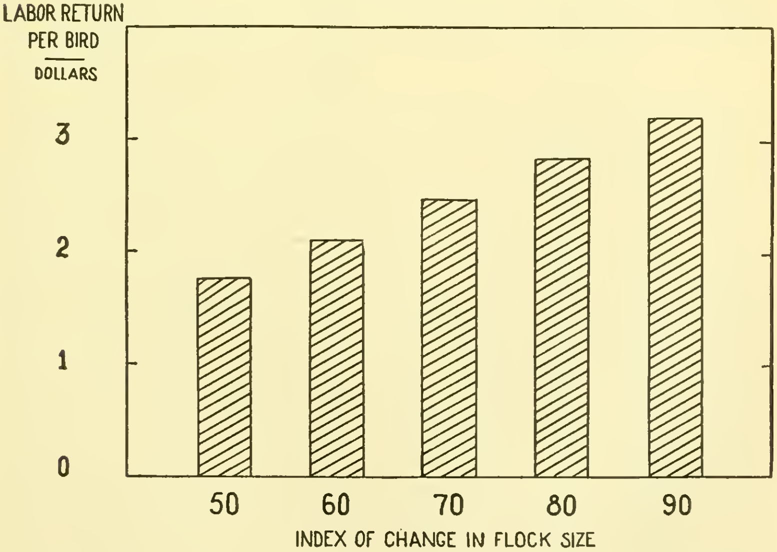
Table 7. Poultry Flocks Classified According to Other Credits than Market Eggs per Bird.

Other Credits than Market Eggs per Bird *Dollars*	Number of Flocks Studied **1926**	 **1927**
Less than 2.00	61	44
2.00— 3.99	45	45
4.00— 5.99	24	23
6.00— 7.99	8	10
8.00— 9.99	2	6
10.00—11.99	4	3
12.00—13.99	0	1
14.00—15.99	0	2
Total	**144**	**134**

Index of Change in Flock Size

Flocks with a low death rate will make a greater labor return than others, and so will flocks in which less culling is necessary. The percentage index of average flock size includes these and other conditions which cause a reduction in flock size during the year. It also includes the effect of an increase or decrease in the number of pullets which are added to the laying flock in the fall months. The average relation between this factor and labor return per bird for the two years studied may be seen in Table 8 and Figure 3.

Figure 3.—Net Relation between Index of Change in Flock Size and Labor Return per Bird, 1927.



The height of the bars represents the average trend of the relationship. An increase of 10 points in index of change in flock size was related to an increase of 36 cents in labor return per bird.

Table 8. Net Differences in Labor Return per Bird Associated with Differences in Index of Change in Flock Size.*

Relation of Average Number of Birds to Initial Number	Labor Return per Bird	
	1926	1927
Per Cent	*Dollars*	*Dollars*
50	1.67	1.75
60	2.04	2.11
70	2.41	2.47
80	2.78	2 83
90	3.15	3.19
100	3.52	3.55
110	3.89	3.91

* With other factors studied held constant at their average values. (See footnote, Table 4, p. 79.)

An increase of 10 per cent in the index of change in flock size was related to an increase of 37 cents labor return per bird in 1926, and 36 cents in 1927. The variation in the index of change in flock size is given in Table 9. The range was from 50 to 130 per cent. The high percentages came about because of an increase in size of flock in the fall over the preceding year.

Table 9. Poultry Flocks Classified According to Index of Change in Flock Size.

Relation of Average Number of Birds to Initial Number	Number of Flocks Studied	
Per Cent	1926	1927
50— 59	11	11
60— 69	13	25
70— 79	29	42
80— 89	54	32
90— 99	24	14
100—109	6	6
110—119	4	2
120—129	2	1
130—139	1	1
Total	**144**	**134**

Death Loss and Culling:—The full extent of disease and death losses in the poultry business cannot be shown from these records, because some cooperators who suffered large losses did not finish the year's record. For those who did complete records, however, Table 10 shows something of the relative importance of deaths and culling. This table gives the cumulated reduction from death and from culling at 3 month intervals from November 1 for all flocks in 1927.

About one-fourth of the flock reduction during the first six months of the year was due to death. This is a serious loss, for a bird lost through death not only decreases the size of the flock, but means one less fowl to sell. A culled bird reduces the size of the flock, but does bring in some income from her sale.

Considerable difference in death loss is shown by the fact that on two-thirds of the farms studied death losses ranged from 5.3 per cent to 17.9 per cent of the initial number.

Table 10. Average Rate of Flock Reduction from Death and Culling, 1927.

At end of:	Per Cent of Initial Number of Birds			Relation of Deaths to Total Reduction
	Died	Culled	Total Reduction	*Per Cent*
3 months	2.7	8.5	11.2	24.2
6 months	6.7	19.2	25.9	25.8
9 months	10.3	37.4	47.7	21.6
12 months	11.6	65.1	76.7	15.1

Differences in death loss and flock reduction did not seem to be related to size of flock. A classification of death losses and total reduction by size of flock showed about the same rate of loss in large and small flocks.

The differences in labor return due to differences in the index of average flock size also suggest that culling may be carried too far by some individuals. Even though a bird is a doubtful producer, it will often pay to keep her as long as she more than pays her feed cost, provided the building space and labor are not needed for other phases of the business. Some poultrymen have been known to maintain an unusually high egg production by the practice of rigid culling. At times and up to a certain limit this may be worth while from the standpoint of advertising, but not necessarily from the point of view of profitable egg production.

Price of Eggs

A brief study of Table 12 will show the fallacy in believing that there is any one price paid for eggs. Some poultrymen wholesale their eggs, while others retail. Some candle and grade to gain higher prices. Rather marked differences in price level also exist between various local markets. These and other causes account for the price variation existing in the state over the same period of time.

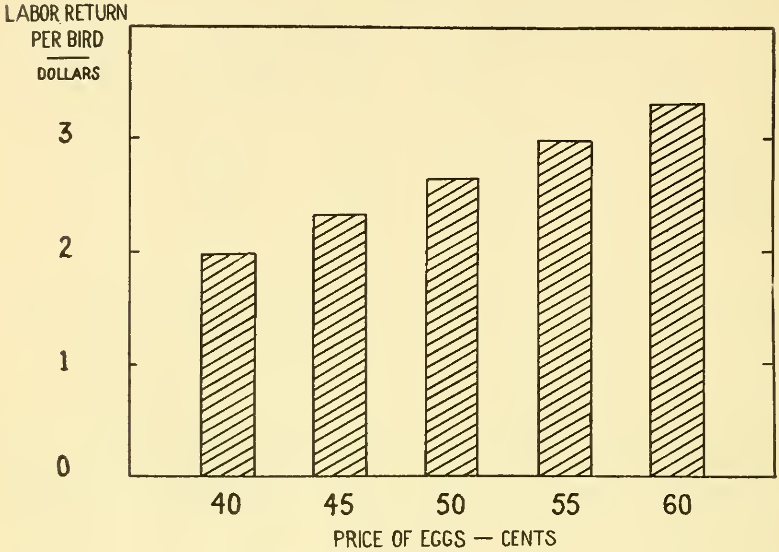
The analysis of the records indicates that price differences affected labor return per bird as shown in Table 11 and Figure 4. For example, in 1927 the average labor return on farms receiving 45 cents for eggs was $2.32 per bird. The average return in another group of farms receiving 55 cents was $2.98 per bird. These two groups of farms were similar with respect to all the factors studied, except price of eggs.

Table 11. Net Differences in Labor Return per Bird Associated with Differences in Average Price Received for Market Eggs.*

Average Price Received for Market Eggs	Labor Return per Bird	
	1926	**1927**
Cents per Dozen	*Dollars*	*Dollars*
40	2.39	1.98
45	2.58	2.32
50	2.78	2.65
55	2.96	2.98
60	3.14	3.32
65	3.33	3.66

*With other factors studied held constant at their average values. (See footnote, Table 4, p. 79.)

Figure 4.—Net Relation between Price Received for Eggs and Labor Return per Bird, 1927.



The height of the bars represents the average trend of the relationship. An increase of 5 cents in average price received for eggs was related to an increase of 33 cents in labor return per bird.

Table 12. Poultry Flocks Classified According to the Average Price Received for Market Eggs.

Average Price Received for Market Eggs (Unweighted)	Number of Flocks Studied	
	1926	**1927**
Cents per Dozen		
40—44	5	11
45—49	37	39
50—54	48	48
55—59	36	21
60—64	13	10
65—69	5	5
Total	**144**	**134**

Fall Egg Production

The net effect of the percentage of fall egg production on labor return per bird was difficult to measure because of intercorrelation with other factors. The simple relationship without allowing for other influences is shown in Table 13.

Fall egg production was found to affect labor return not only through more favorable prices but also because of its influence on the annual egg production. The relation of each of these factors to fall production was analyzed separately.

Table 13. Gross Differences in Labor Return Associated with Differences in Fall Production.*

Per Cent of Year's Egg Production in 4 months September-December	Labor Return per Bird 1927 *Dollars*
10	1.25
15	1.80
20	2.36
25	2.92
30	3.48
35	4.04

*Without allowing for possible influence of other factors.

Table 14. Poultry Flocks Classified According to Fall Egg Production.

Per Cent of Year's Egg Production in 4 months September-December	Number of Flocks Studied	
	1926	**1927**
5— 9	1	4
10—14	14	12
15—19	29	26
20—24	39	27
25—29	33	31
30—34	16	20
35—39	8	12
40—44	4	2
Total	**144**	**134**

Price curves for the two years studied are given in Figure 5. The highest prices were received in the four months September to December. The average price in the four months was about 21 cents above the average price for the other eight months in 1927.

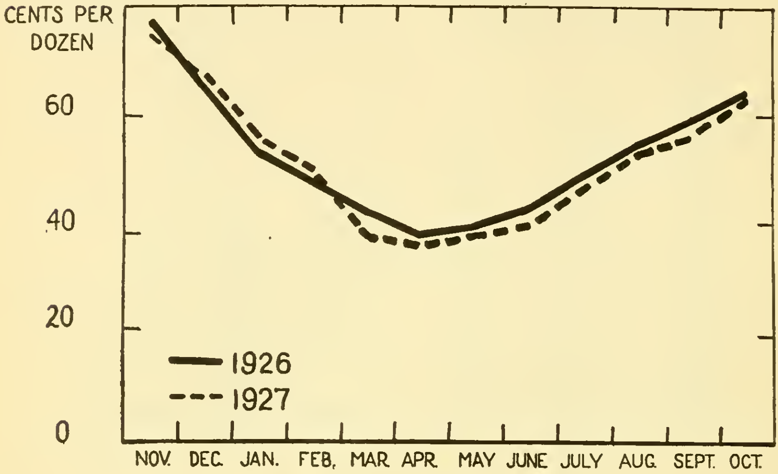
After first correcting for differences in prices not related to season, the relation shown in Table 15 was obtained. Those poultrymen who had 30 per cent fall production received 3.3 cents per dozen more for all the eggs sold in the entire year than did those who had only 20 per cent fall production.

Table 15. Differences in Annual Egg Production per Bird, and in Weighted Average Price Received for Eggs, Accompanying Differences in Fall Egg Production, 1927.

Per Cent of Annual Egg Production in 4 Months September-December	Annual Egg Production per Bird	Weighted Average Price*
10	126	44.8
15	134	46.5
20	142	48.1
25	150	49.8
30	158	51.4
35	166	53.1

*After first correcting for differences in unweighted prices.

Figure 5.—Average Monthly Prices Received for Eggs by Poultry Cooperators, Years Ending October 31, 1926, and October 31, 1927.



A very close relationship also existed between fall egg production and total annual egg production. Table 15 shows this relationship for the 1927 records. Recent work by Hays and Sanborn[1] shows that hatching before April 15 tends to increase persistency and hence total annual egg production. The relation shown in Table 15 probably results partly from this tendency. It may also be due in part to the fact that poultrymen with high laying strains of birds had earlier hatching dates and got their birds into production earlier in the fall.

Relative Importance of the Factors

The relation between differences in labor return and differences in each of the factors studied has been considered. It remains to point out the relative significance of the several factors. This cannot be determined directly by comparing the tables showing the relation between each factor and labor return per bird, because the units in which the factors are expressed are not the same.

The following table places the factors on a uniform basis with respect to this difficulty by showing the effect on labor return of a change of a unit of variation in each factor.

---

[1] Hays, F. A. and Sanborn, Ruby. Annual Persistency in Relation to Winter and Annual Egg Production. Mass. Agr. Expt. Sta. Tech. Bul. 9, 1926.
Intensity or Rate of Laying in Relation to Fecundity. Mass. Agr. Expt. Sta. Tech. Bul. 11, 1927.

An increase of one Unit* of Variation in:	Was accompanied by an increase in labor return per bird of: 1926 cents	1927 cents
Egg production	85	82
Price of Eggs	20	37
Index of change in flock size	54	51
Other credits than market eggs	80	101

* The Unit of Variation used for each factor is the statistical measure known as the standard deviation.

This table indicates that, in general, differences in poultry profits in both years can be attributed more to differences in egg production and in other credits than to differences in price of eggs and in index of change in flock size. On the other hand it also shows that all four factors were responsible for important variations in labor returns per bird. In many individual cases the differences in price received for eggs and in loss from flock reduction were more important than egg production and diversity.

Conclusions

The results of this study show the average dollar and cents differences in labor return which accompanied differences in egg production per bird, price received for eggs, diversity in the enterprise, index of change in flock size, and fall egg production. In other years, the relationships would be changed depending on the economic situation, the technical status of the industry, and other factors.

Differences in egg production and in other credits were found to be more closely related to labor return per bird than differences in price received for eggs and in index of change in flock size. However, the wide variation in each factor showed that there was a considerable range of opportunity for profitable changes in all four factors.

This study emphasizes the value of keeping poultry records. Only by keeping some sort of simple flock records will the poultryman be able to compare the performance of his flock with the results from this and other studies and thus definitely pick out the weak places in his business.

TECHNICAL APPENDIX

In the foregoing part of the bulletin, the emphasis was placed on the presentation of the results secured from the study rather than upon the statistical method used in arriving at the results. Some readers may be interested in knowing more about the methods used in the analysis. For their benefit the following technical section is included.

For the statistical analysis the factors previously discussed were expressed in the following terms:

A. Index of change in flock size, in terms of the percentage which the average number of birds is of the initial number.

B. Annual egg production per bird; the sum of the monthly averages for each flock.

C. Price of eggs; the sum of the monthly average prices for each flock, divided by 12.

D. Fall egg production in the four months September through December, expressed as a percentage of the total production for the year.

E. Other credits than market eggs; credits from all sources except market eggs, expressed in dollars per bird.

F. Size of flock; the November 1 inventory figure for all females at the beginning of the record year.

G. Labor return from the entire flock.

H. Labor return per initial bird.

Three problems were worked through. The first one took labor return from the entire flock in 1927 as the dependent variable. Because of the great differences in size of flock, as shown in Table 16, this factor was so important as to overshadow most of the others. Consequently it was thought best in the other analyses to eliminate the factor of size of flock from the problem and to make labor return per bird the dependent factor. This reduced the total correlation but brought out more clearly the relationship between the other factors involved.

Table 16. Poultry Flocks Classified According to Initial Size.

Initial Number of Birds per Flock	Number of Flocks Studied 1926	1927
0— 99	23	20
100— 249	51	34
250— 499	33	36
500— 749	15	22
750— 999	11	8
1000—1249	2	4
1250—1499	2	6
1500—1749	1	1
1750—1999	3	2
2000 and over	3	2
Total	**144**	**134**

The probable errors of estimate in Table 17 are valuable in showing the closeness with which the labor returns could be estimated in the respective years. The measure tells something about how much was left unexplained. The probable error of estimate for labor return per bird in 1927, for example, means that by use of the regressions we were able to estimate the labor returns and have half of the estimates fall within 78 cents of the actual labor returns.

Table 17. Multiple Correlation Coefficients and Probable Errors of Estimates

Coefficients	Per Flock 1927	Per Initial Bird 1927	 1926
Multiple Correlation R=	.904 ± .011	.820 ± .019	.797 ± .020
Probable Error of Estimate for Labor Return	$473	$0.78	$0.76

The Importance of the Individual Factors

The relative importance of the several factors in the two analyses which took labor return per bird as the dependent factor were as follows:

	Per Cent Determination 1926	 1927
A. Index of Change in Flock Size	14.0	10.4
B. Annual Egg Production per Bird	26.7	22.1
C. Price of Eggs	0.5	2.5
D. Fall Egg Production	0.1	— 0.5
E. Other Credits than Market Eggs	22.2	32.6
Combined Importance of A, B, C, D, and E	**63.5**	**67.1**
Residual Variation	36.5	32.9
Total	**100.0**	**100.0**

This indicates that the most important factors affecting labor return per bird are annual egg production per bird and other credits than market eggs. Next comes index of change in flock size. The price of eggs and the fall egg production are really more important than these coefficients indicate, because of intercorrelation with annual egg production.

Further light on the price of eggs is furnished by a study of the relative variability of the factors considered. The coefficients of variability (computed by expressing the standard deviations as percentages of the respective means) were as follows in the two years:

Factor	Coefficients of Variability 1926 *Per Cent*	 1927 *Per Cent*
Index of change in flock size	18.7	18.0
Annual egg production	20.2	18.2
Price of eggs	10.2	10.8
Fall egg production	29.9	30.1
Other credits than market eggs	84.6	79.9

This means that the variability (or difference from farm to farm) in the price of eggs was considerably less than the variability in the other factors studied. Hence the variability in labor return due to differences in price received for eggs is less than the variability due to the other factors.

To measure the relative influence on egg receipts of differences in egg production and in price received for eggs, a simple correlation calculated between egg receipts and egg production for 1927 gave r= .82 and r^2= 67 per cent. Therefore, since egg production and average price almost completely determine receipts from eggs, variations in egg production were about twice as important as variations in price in affecting egg receipts in 1927.

Approximately two-thirds of the variation in labor return per bird can be explained in terms of four of the factors studied. The remaining variation is due to factors not included in the study, probably for the most part differences in feed consumption and cost factors. The discussion in the preceding section of the principal variables and their relation to labor return per bird completes the picture of the significance of each of the factors.

Other Factors and Unexplained Variation

It will be of interest to refer to the total variation in labor return per bird and see how much of it has been accounted for by the factors which have been considered. In 1927 the variation in labor return per bird was from $ .66 to $11.52. The labor returns per bird estimated from the regressions varied from $0.18 to $8.04. The fact that the regression formula gave estimated values for labor return per bird, half of which fell within a range of about 78 cents either way from the actual labor return, indicates the degree of reliability of the study as a whole. This is fairly good, but since the multiple correlation was by no means perfect, (leaving 32.9 per cent of the squared variation unaccounted for), other factors not studied must have had considerable influence. A small part of the variation is always due to errors in the collection of the data, but in this case it seems probable that variations in cost factors, particularly feed, may account for a large part of the remaining differences.

In order to test the truth of this assumption an analysis was made of the relationship between costs and the unexplained or residual variation for the 1927 records.[1] The correlation between the residuals and total costs was found to be $r = .28$. It appeared from dot charts that this was about as much as would be found between feed costs and the residuals. A correlation coefficient of $r = .28$, although not high, has some significance and shows that costs did account for a part of the differences not explained. Using the regression from the correlation as a correction formula, new estimates were made, and new residuals computed to determine how much closer the average estimate was. The probable error of estimate was cut down from 78 cents to 65 cents and the average deviation of the residuals was changed from 76 cents to 71 cents.

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[1] Residuals were computed by first estimating labor returns from the regression equation and then subtracting the estimates from the actual labor returns.

Table 18. Simple Correlations* with Labor Return per Bird, for Six Factors, and Intercorrelations. (134 Poultry Farm Records, 1927)

Factors Correlated	Index of Change in Flock Size A	Annual Egg Production B	Price of Eggs C	Fall Egg Production D	Other Credits than Market Eggs E	Size of Flock F
X (Labor Return per Bird)	+.41	+.54	+.13	+.42	+.66	—.02
A	....	+.13	—.15	+.22	+.23	—.10
B	....	....	—.10	+.45	+.25	+.06
C	....	....	....	—.06	+.00	—.22
D	....	....	....	....	+.40	+.16
E	....	....	....	....	....	+.17

*With 134 records, a correlation coefficient of zero would have a probable error of ± .058. Hence any correlations of 0.18 or over may be regarded as probably not due to chance variations.

Table 19. Net Correlations* with Labor Return per Bird, for Five Factors, and Intercorrelations. (134 Poultry Farm Records, 1927)

Factors Correlated	Index of Change in Flock Size A	Annual Egg Production B	Price of Eggs C	Fall Egg Production D	Other Credits than Market Eggs E
X (Labor Return per Bird)	+.39	+.53	+.31	—.05	+.62
A	....	—.19	—.16	—.12	—.12
B	....	....	—.24	+.33	—.27
C	....	....	....	—.01	—.16
D	....	....	....	....	+.26

*With 134 records, a correlation coefficient of zero would have a probable error of ± .058. Hence any correlations of 0.18 or over may be regarded as probably not due to chance variations.

Publication of this document approved by the
Commission on Administration and Finance

3 M.-5-'29. No. 5794

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 252 JUNE, 1929

Supplements for Copper Fungicides

E. B. Holland, C. O. Dunbar, and G. M. Gilligan

Ever since copper fungicides were introduced, numerous supplementary products have been recommended for incorporation in the spray with a view to remedying some real or fancied defect. The contradictory evidence presented by different investigators relative to various supplements may be due in part to differences in amount of substance employed, in method of preparation and of application, but more often to an insufficient number of replications with different crops under varying weather and soil conditions. The use of supplements is not warranted unless they reduce infection and consequent economic losses. This study was undertaken to determine the intrinsic and relative values of the materials recommended for use as supplements.

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AGRICULTURAL EXPERIMENT STATION
AMHERST, MASS.

SUPPLEMENTS FOR COPPER FUNGICIDES

By E. B. Holland, Research Professor of Chemistry, and C. O. Dunbar and G. M. Gilligan, Research Assistants in Chemistry[1]

Introduction

Ever since copper fungicides were introduced, numerous supplementary products have been recommended for incorporation in the spray with a view to remedying some real or fancied defect. This applies particularly to Bordeaux mixture but also to Burgundy and the acetates. In many cases the reputed defects were due probably to faulty methods of preparation or of application, although in some instances the claims were well founded and deserve attention. Most of these shortcomings have been enumerated by different investigators in some form or other and various treatments suggested for their amelioration, of which the following are the most important:

1. To increase the activity of the fungicide by increasing the concentration of the copper ions.
2. To increase suspension by deflocculating the fungicide, by increasing the viscosity of the dispersion medium, or both.
3. To increase wetting power by reducing the interfacial tension at the leaf-spray interface and thereby facilitate spreading and distribution.
4. To increase adhesiveness by forming more resistant deposits.
5. To prevent or reduce crystallization or decomposition by the addition of protectors.
6. To prevent or reduce interactions between fungicides and insecticides in combined sprays.
7. To increase visibility of the deposit.

As a rule supplementary products are added for a specific purpose, but their influence is manifested generally in more than one direction due to the interdependence of the various attributes of a spray. Space does not permit an adequate review of the literature on the subject but attention is called to some of the earlier investigations.

1. To increase the activity of the fungicide by increasing the concentration of the copper ions.

The toxicity of a salt in solution is equal to the combined toxicity of its base and acid or, according to Kahlenberg and True (47)[2] for the various copper salts, to the combined action of its ions; but Coupin (18), Clark (16, p. 37, 40) and Pickering (3, p. 127) have shown that in dilute solutions the action of the acid radical is negligible, although Bain (1, p. 27, 28) noted some exceptions. Pfeffer (73, p. 273, 274) claims that the physiological action of poisons increases with the degree of ionization although undissociated portions may be active, and that non-electrolytes are also poisonous and may undergo chemical decomposition in a way analogous to the dissociation of electrolytes whereby the poisonous properties are altered. From the above one concludes that the copper in fungicides must not only be soluble but ionized to become active, and that the activity is proportional to the concentration of the copper ions and the potential availability to the total ionizable copper, although the copper in undissociated compounds may undergo decomposition and become appreciably active. Soluble copper in itself is not a true criterion of activity.

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[1] With the cooperation of Dr. E. F. Guba, Assistant Research Professor of Botany.

[2] Reference is made by number to Literature Cited p. 108.

A considerable range in activity may be obtained with different fungicides, such as basic, slightly alkaline, neutral, and acid Bordeaux mixtures. Burgundy, the acetates, cuprammoniums and copper sulfate, and with different concentrations: but toxicity to foliage, poor adhesiveness, invisibility and difficulty of preparation practically preclude the use of some of these products. Supplements, however, have been employed by various workers and the process generally consists of adding to Bordeaux or Burgundy mixtures substances known to produce soluble copper in alkaline mixtures. These substances may be divided into three groups (a) sugars, etc. (b) hydroxy-organic acids and (c) biuret compounds. The resulting soluble compound is usually electronegative and the solution purple or violet.

(a) Of the first group may be mentioned sucrose, dextrose, lactose, dextrin and glycerol. They produce soluble copper, but mixtures with dextrose, lactose and dextrin are particularly liable to decompose on standing, with the precipitation of cuprous oxide which is not rated highly as a fungicide.

In numerous tests with Bordeaux 4-2-50 in the station laboratory, soluble copper was observed with 0.016 per cent sucrose, 0.080 per cent lactose, 0.160 per cent dextrin and 0.801 per cent glycerol, but probably occurred in lower concentrations. In most instances the Bordeaux was made with dry, laboratory-prepared hydrated lime after being soaked over night. The amount of added substance varied generally from 0.008 to 0.160 per cent of the spray although larger amounts were employed occasionally.

Many investigators have used sugar and molasses with Bordeaux, Burgundy and special mixtures in field practice. Pons (77), Perret (71, 72) and Barth (cited 5, p. 295, 296) claim that such preparations are more active, non-toxic to foliage and of good suspension and adhesive properties. Doran (22, p. 541) found that sugar and molasses increased the toxicity of Bordeaux to conidia of apple scab fungus. The reaction between Bordeaux and sugar, excluding the calcium hydroxide, is said to be substantially as follows:

$$C_{12}H_{22}O_{11}+H_2O=2C_6H_{12}O_6$$

$$2C_6H_{12}O_6+3O_2=2(CHOH)_4(COOH)_2+2H_2O.$$

$$2(CHOH)_4(COOH)_2+2CuSo_4\ 5H_2O=2(CHOH)_4(COO)_2\,Cu+2H_2SO_4+10H_2O.$$

According to the above equation, 1 part of sugar converts 1.46 parts of copper sulfate into 1.59 parts of copper saccharate and renders soluble 0.37 parts of copper. Investigators recommend generally 5 per cent as much sugar or 10 per cent as much molasses as of copper sulfate which, if applied to Bordeaux 2-2-50 and 4-4-50, would yield approximately 0.01 per cent and 0.02 per cent soluble copper.

(b) Pickering (75, p. 174, 184, 190) and others have shown that hydroxy-organic acids such as citric, gallic, glyceric, lactic, malic, saccharic, salicylic and tannic acids, in the presence of alkalies, form soluble cupri compounds with a small amount of basic salt in some instances. The structural formulae of the cupri compounds lack confirmation. Organic acids that do not contain alcoholic hydroxyls form insoluble basic salts under the same conditions.

In tests made at this laboratory with Bordeaux 4-2-50, soluble copper was observed with 0.048 per cent gallic, 0.048 per cent pyrogallic and 0.080 per cent tannic acids but probably occurred in lower concentrations. Although hydroxy-organic acids produce soluble copper with Bordeaux and Burgundy mixtures, and are less likely to yield cuprous oxide, there is very little information available relative to their practical use in this connection. The soluble copper produced by the action of sugars and of hydroxy acids in the presence of alkalies is presumably a true solution.

(c) Albuminous substances containing two amino (NH_2) groups linked to different carbon atoms, so-called biuret compounds, also produce soluble copper in the presence of alkalies. Of the more common substances may be mentioned gelatine, glue, casein, albumen, milk and calcium caseinate, although they are seldom employed for this purpose.

In tests with Bordeaux 4-2-50 in the station laboratory, soluble copper was observed with 0.048 per cent glue and 0.160 per cent casein[3]; and in the case of Bordeaux 4-4-50 with 0.05 per cent gelatine, and 0.05 per cent glue; and traces with 0.10 per cent casein and 0.10 per cent albumen on standing 24 hours. In additional tests with Bordeaux 4-4-50 and 0.10 per cent protector, a trace of soluble copper was observed with albumen, increasing with casein and glue to an appreciable amount with gelatine which gave a purple solution. The soluble copper produced by biuret compounds seems to be colloidal as it did not pass a collodian sack and apparently exhibited Brownian movement (Gilligan), but requires further investigation.

All the soluble organic copper compounds mentioned are evidently less active and less toxic to foliage than like amounts of soluble copper in inorganic combination and yet may prove of service in some instances. The supplements may also increase wetting and spreading and possible adhesiveness in the case of some proteids.

2. To increase suspension by deflocculating the fungicide, by increasing the viscosity of the dispersion medium, or both.

The suspension of copper fungicides depends largely on the degree of dispersion and the character of the particles, as added substances seldom have a noticeable deflocculating action but merely retard subsequent agglomeration and increase the viscosity of the dispersion medium. Light amorphous products naturally have a higher power of suspension than those of a dense, crystalline character.

Several references have been noted. Kelhofer (49) claims that sugar increases the suspension of Bordeaux; Neuweiler (65) that 0.01 to 0.20 per cent of tannin is effective; and Winston, Bowman and Yothers (97) that 1 per cent of oil emulsion with Bordeaux 3-3-50 settles less rapidly.

An effort was made to determine the effect of numerous substances on the suspension of Bordeaux mixture made from different batches of dry, laboratory-prepared hydrated lime after being soaked over night. The hydrate was not air-separated and undoubtedly was less uniform in composition and size of particles than many brands of chemical hydrated lime. The relatively lower suspension of the resulting Bordeaux would be expected to respond more readily to the influence of added substances. Considerable variation is inevitable, however, due to inability to control the reaction. Bordeaux 4-2-50 was adopted as preferable to that of a higher lime content, and the amount of added substance (usually called a protector) generally ranged from 0.008 to 0.160 per cent of the spray, although larger amounts were occasionally employed. In the latter case the mixtures were apparently less susceptible to other factors, but excessive dilution of the spray residue is considered objectionable in that it may reduce materially the effectiveness of the fungicide or in some instances even the physiological activity of the plant. The added substance was dissolved or dispersed as thoroughly as possible. With extractives the coarse material was removed by screening. A poorly dispersed protector tends to have an effect on the suspension of Bordeaux similar to that of coarse particles of lime. In some instances the inherent properties may be more than offset by poor dispersion. The solution of copper sulfate was added to the soaked hydrated lime and then the protector added, thoroughly mixed and suspension readings taken at the end of 1, 2 and 3 hours. These tests were conducted in rubber-stoppered, glass museum jars of the following dimensions: total height, 305.5mm (14 inches); length and outside diameter of the body, 303.0 by 63.5 mm (13.0 by 3.5 inches) and capacity to the neck, 850 to 900 cc. The length of the column for a volume of 780 cc was determined for each jar and the results calculated in percentage.

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[3] Dissolved in sodium hydroxide in this instance.

Among the substances tested were sugars, dextrin, starches, gums, gum resins, soapbark extract, pectin extracts, mucilaginous extracts, miscellaneous extracts, glycerol, proteids, organic acids, salts of organic acids, soaps, inorganic salts, earths, etc. The data are too voluminous to permit their publication in entirety, but by excluding most mixtures that settled more than 10 per cent an hour, a reasonable tolerance, many of the substances are eliminated entirely and only average results are reported on those retained. The averages do not represent an equal number of tests. As a rule, the more promising the results, the more determinations were made in confirmation. An increase in suspension with an increasing amount of substance within limits that are permissible, and the uniformity of results with a given amount, were considered a criterion of the effectiveness of the substance employed.

The sugars—dextrose, lactose, levulose, manitose and sucrose—did not appear to have an appreciable influence on the suspension of Bordeaux 4-2-50 although occasionally a test with 0.016 per cent came within the tolerance. Powdered dextrin, British gum, arrowroot-starch (Maranta), inulin (Alant) and soluble starch (amylo-dextrin) did not increase suspension within the limits tested. Gum arabic (Acacia), at the rate of 0.080 to 0.160 per cent may have had a slight influence, but tragacanth proved less satisfactory although tests of 0.024 per cent were passable. Several gum resins were employed but required a solvent and did not increase suspension.

Soapbark (Quillaja) extract containing saponin had no effect. Several pectin extracts were tested, of which fruit pectin proved of no value; agar-agar, at the rate of 0.024 to 0.048 per cent, probably some; Iceland moss (Cetraria), less and not dependable; and Irish moss (Chondrus), of no value. The mucilaginous extracts were slightly more promising:—no increase in suspension was obtained with licorice (Glycyrrhiza); slight increase, with 0.080 to 0.160 per cent of linseed (Linum), both flaxseed meal and the fat extracted residue; considerable increase, with 0.016 to 0.160 per cent of quinceseed (Cydonia); and slight increase, if any, with slippery elm (Ulmus). Miscellaneous extracts from corn stover, hay and rye straw, used at the rate of 0.801 to 1.603 per cent, increased suspension appreciably; but to ascribe their action to definite compounds would be difficult. Glycerol was of no value. Of the proteids, neither gelatine nor glue increased suspension. In subsequent tests, 0.10 per cent of albumen, casein, gelatine and glue with Bordeaux 4-4-50, using chemical hydrated lime, did not increase suspension. Albumen and casein would not disperse satisfactorily in water.

Various organic acids—butyric, citric, gallic, lactic, pyro-gallic, tannic and tartaric acids—were employed, of which tannic acid at the rate of 0.016 to 0.080 per cent improved suspension. Salts of organic acids, such as calcium caseinate, sodium albuminate, benzoate, caseinate, oleate and resinate, gave no increase. Several of these substances were laboratory prepared and probably carried an excess of sodium hydroxide. Castile and resin soaps were of no apparent value, but soap powder at the rate of 0.016 to 0.801 per cent increased suspension. Soaps are objectionable, however, in that they react with lime on standing to form a curdy precipitate.

Of the inorganic substances, calcium and magnesium silicates and aluminum hydroxide proved of no value, but liquid sodium silicate at the rate of 0.032 to 1.603 per cent, increased suspension. The dry silicate was less effective. Bordeaux so treated, however, tends to peel from the leaves on drying (Dunbar). Bentonite, clay, fuller's earth, infusorial earth, Perkin's earth, talc and Wilkinite were also employed. Of these, 0.016 to 0.160 per cent of Bentonite and 0.048 to 0.160 per cent of Wilkinite proved of value. These are yellow "ball" clays of similar characteristics, and with fungicides, other than Bordeaux with excess lime, may serve to increase the visibility of the spray residue.

The results obtained with the more promising supplements affecting suspension are reported in Table 1.

Tannic acid, Bentonite and Wilkinite were the most dependable substances employed for increasing the suspension of Bordeaux mixture, although quinceseed extract, soap powder and sodium silicate deserve mention. Other substances may prove serviceable under different conditions or in larger amounts: but whether their use with a more highly dispersed lime is warranted, is an open question and depends somewhat on other considerations such as ability to increase wetting, spreading and adhesiveness and to retard decomposition. Lovett (58) claims that suspension in itself is a fair indication of power to spread, and most workers will concur in principle. The substances reported may prove of value with other copper fungicides but probably not to the same degree.

Table 1.—Suspension of 4-2-50 Bordeaux with Various Supplements.

Supplement	Hours	Percentage of Supplement Added:									
		0 000	0.008	0 016	0.024	0 032	0.048	0 080	0.160	0.801	1.603
		Percentage Suspension									
Check (average 28 tests)	1	82.1	...	...	...	...	...	...	...	...	...
	2	62.8	...	...	...	...	...	...	...	...	...
	3	53.0	...	...	...	...	...	...	...	...	...
Gums											
Arabic	1	...	91.0	82.9	92.4	85.9	91.1	91.9	91.6	...	...
	2	...	61.9	65.2	73.3	75.4	82.0	83.2	83.5	...	...
	3	...	49.9	56.8	57.4	68.0	74.0	73.9	76.3	...	...
Tragacanth	1	...	91.0	85.9	90.8	72.7	70.9	...	...	...	...
	2	...	79.9	69.9	81.5	64.3	64.2	...	...	...	...
	3	...	65.9	60.7	72.0	60.1	60.7	...	...	...	...
Pectin Extracts											
Agar-Agar	1	...	90.9	89.3	91.6	88.4	89.7	81.1	...	...	...
	2	...	66.9	79.3	81.6	68.5	80.9	73.0	...	...	...
	3	...	55.7	70.8	71.0	70.8	74.5	68.7	...	...	...
Iceland Moss	1	...	87.9	90.8	86.7	84.7	85.6	94.1	...	...	...
	2	...	67.1	77.0	65.7	61.0	62.0	87.2	...	...	...
	3	...	55.2	67.5	56.6	53.9	55.6	79.8	...	...	...
Mucilaginous Extracts											
Flaxseed Meal	1	...	...	80.9	...	89.4	90.5	90.9	93.4	...	...
	2	...	...	59.2	...	72.9	74.2	80.0	85.7	...	...
	3	...	...	53.5	...	59.1	62.9	69.8	78.3	...	...
Linseed Meal (ether extracted)	1	...	...	77.7	...	70.9	76.8	89.4	...	...	...
	2	...	...	64.6	...	58.3	73.7	78.9	...	...	...
	3	...	...	56.5	...	53.1	62.8	69.7	...	...	...
Quince Seed	1	...	92.0	92.3	90.6	92.2	92.3	94.1	96.2	...	...
	2	...	81.1	83.3	80.5	83.3	84.4	88.1	92.4	...	...
	3	...	69.4	74.3	71.5	74.1	76.8	82.1	88.2	...	...
Slippery Elm	1	...	85.9	89.7	...	90.8	88.7	94.4	...	...	...
	2	...	59.9	78.4	...	79.9	67.6	86.3	...	...	...
	3	...	47.2	65.5	...	68.0	58.4	74.4	...	...	...
Miscellaneous Extracts											
Corn Stover	1	...	...	...	...	...	87.6	84.4	87.9	96.5	97.5
	2	...	...	...	...	...	63.5	66.0	65.6	92.6	94.7
	3	...	...	...	...	...	56.0	58.9	58.9	89.1	91.9
Hay	1	...	...	...	...	...	90.1	80.5	91.1	95.1	95.8
	2	...	...	...	...	...	76.9	61.3	81.6	89.8	91.2
	3	...	...	...	...	...	64.2	55.3	71.3	84.2	86.7
Rye Straw	1	...	...	...	...	...	...	...	...	92.6	94.4
	2	...	...	...	...	...	...	...	...	84.2	88.5
	3	...	...	...	...	...	...	...	...	75.1	82.5
Organic Acids											
Tannic	1	...	...	91.7	...	93.7	95.0	95.4	...	...	...
	2	...	...	82.2	...	85.8	88.7	89.7	...	...	...
	3	...	...	73.1	...	77.4	82.3	84.5	...	...	...
Soaps											
Powder	1	...	...	90.8	...	90.9	92.5	92.9	92.7	97.2	81.6
	2	...	...	80.6	...	80.7	83.9	85.3	84.7	89.6	67.0
	3	...	...	70.4	...	70.5	75.3	77.4	77.2	83.7	57.6
Inorganic Salts											
Sodium Silicate (liquid)	1	...	...	92.5	...	92.0	91.2	92.6	94.2	97.2	95.8
	2	...	...	80.4	...	83.9	81.9	84.8	87.6	93.3	93.5
	3	...	...	70.0	...	75.9	72.3	75.5	79.6	89.0	90.0
Sodium Silicate (dry)	1	...	...	88.3	...	...	90.4	90.8	93.6	...	...
	2	...	...	74.8	...	...	80.1	80.5	86.2	...	...
	3	...	...	60.6	...	...	69.9	70.6	78.7	...	...
Earths											
Bentonite	1	...	89.0	92.5	...	92.2	...	95.4	95.4	...	...
	2	...	73.4	81.6	...	84.0	...	92.5	91.5	...	...
	3	...	59.6	71.6	...	75.9	...	87.2	86.9	...	...
Wilkinite	1	...	...	...	...	...	94.3	95.7	95.6	...	...
	2	...	...	...	...	...	88.3	90.8	92.9	...	...
	3	...	...	...	...	...	82.3	85.8	89.0	...	...

3. To increase wetting power by reducing the interfacial tension at the leaf-spray interface and thereby facilitate spreading and distribution.

A highly dispersed copper fungicide assures better suspension and more uniform distribution than one of larger aggregates, especially when applied as a mist or film of invisible drops. Greater adhesiveness of the resulting residue is also obtained. Drench applications on the other hand are more likely to collect in drops, particularly on the edge of the leaves, or run off carrying most of the fungicide. The force with which the spray is applied is also a factor in wetting and spreading. The resistance of leaves to wetting varies with the character of the leaf surface (epidermis) and the nature of the spray solution. The epidermis of leaves may be a relatively thin membrane of cellulose or heavily cutinized (cuticularized), waxy, hairy, etc., and differs greatly in respect to wetting. The same applies in a measure to fruits, buds, spurs and older growth. The leaves of apples, peaches, pears and grapes are cutinized, and fruits like apples and plums and the leaves of the cabbage are waxy and not easily wet as they interpose a film of air between the leaf and spray. In most instances, the addition to the spray of organic substances of similar constitution to those in the plant, i. e., albuminous substances and plant infusions, and their adsorption or surface concentration at the leaf-spray interface, reduces the interfacial tension and permits the spray to touch, wet and form a continuous film over the surface. In the case of waxy surfaces, the substances added generally have a fairly large molecule with a small, active group soluble in water and with the inactive portion adsorbed in the surface layer of the spray solution. When the inactive portion is similar to or soluble in the wax, its adsorption at the leaf-spray interface reduces the interfacial tension and permits the spray to spread. Soap and soap emulsions, when compatible with the fungicide, are usually effective on such surfaces and other substances will be noted.

It is evident, therefore, that wetting is essentially the same on all plant surfaces and that an effective solute must have a low surface tension (soaps), or the property of surface concentration (saponin, proteids), and, in some instances, a solvent action on the epidermal coating in addition. Since there is no method for measuring interfacial tension between plant surfaces and spray and as the nature of the surface interposed by the plant is problematical, it is impossible to foretell the action of added substances known to reduce surface tension of the spray solution on the plant surface-spray interface. The fact remains, however, that an increase in wetting and spreading is necessary in many instances, is desirable in all cases, and is secured mainly by reducing the interfacial tension. Therefore, the substances to be added for the various leaves, fruits and other surfaces must be determined largely by trial and error.

Theory of Wetting and Spreading.

Numerous investigators have contributed extensively on the subject and a few will be noted. Mausier (62), Gastine (32) and Ruth and Kelly (82) found a low surface tension of the spray favored spreading. Brunnich and Smith (6) assert that wetting power depends primarily on surface tension. Lovett (58) claims that neither suspension nor viscosity of the spray solution is a true index of spreading but considers suspension indicative and later (59) a desirable attribute, although not a definite criterion. Vermorel and Dantony (90) state that spreading occurs when the cohesion of the molecules of the liquid is less than double their adhesion for the solid and correlate a low "static" surface tension with spreading, but subsequently decided (91) that it is not an index and that a high surface viscosity has greater influence. Lefroy (56) states there are three surface tensions—spray, leaf and interface—involved in spreading and that the first should be low but the others cannot be determined. Willows and Hatschek (96) claim that the adsorption or concentration of a solute at the liquid-solid interface reduces interfacial tension. Cooper and Nuttall (17) accept the Quincke (79) theory,—that if the surface tension of the solid is greater than the sum of the surface tension of the spray and of the interface, spreading will occur; but believe the solvent action of the spray on the solid and the surface concentration of the solute, with a high surface viscosity, may vitiate the equation. They consider that interfacial tension alone will suffice for comparative purposes, and with soap solutions is directly proportional to the drop number (stalagmometer reading), since spreading varies inversely with interfacial tension. The general formula for the wetting of a solid by a liquid, as given by Nuttall (66, p. 38), is as follows:

$$T_2 \text{ must be} > T_1 \div_{12}$$

T_1 surface tension of liquid/air.
T_2 surface tension of solid/air.
T_{12} interfacial tension of liquid/solid.
Thus, spreading can be increased by reducing the surface tension of the spray or of the leaf-spray interface and T_2 and T_{12} are indeterminate.

liquid may not wet

CORRECTION

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The formula on page 101 should read:

$$T_2 \text{ must be} > T_1 + T_{12}$$

crease wetting and spreading include substances, ployed in this Station for increasing suspension (Sec. 2) and in addition emulsions, creosote, some phenol derivatives and several of the higher alcohols. There is apparently a clear line of demarcation between wetting, spreading and distribution and adhesiveness and yet the two issues are sometimes confused. Furthermore, the results are generally based on the character of the wetting and the visible deposit on the foliage—a matter

3. To increase wetting power by reducing the interfacial tension at the leaf-spray interface and thereby facilitate spreading and distribution.

A highly dispersed copper fungicide assures better suspension and more uniform distribution than one of larger aggregates, especially when applied as a mist or film of invisible drops. Greater adhesiveness of the resulting residue is also obtained. Drench applications on the other hand are more likely to collect in drops, particularly on the edge of the leaves, or run off carrying most of the fungicide. The force with which the spray is applied is also a factor in wetting and spreading. The resistance of leaves to wetting varies with the character of the leaf surface (epidermis) and the nature of the spray solution. The epidermis of leaves may be a relatively thin membrane of cellulose or heavily cutinized (cuticularized), waxy, hairy, etc., and differs greatly in respect to wetting. The same applies in a measure to fruits, buds, spurs and older growth. The leaves of apples, peaches, pears and grapes are cutinized, and fruits like apples and plums and the leaves of the cabbage are waxy and not easily wet as they interpose a film of air between the leaf and spray. In most instances, the addition to the spray of organic substances of similar constitution to those in the plant, i. e., albuminous substances and plant infusions, and their adsorption or surface concentration at the leaf-spray interface, reduces the interfacial tension and permits the spray to touch, wet and form a continuous film over the surface. In the case of waxy surfaces, the substances added generally have a fairly large molecule with a small, active group soluble in water and with the inactive portion adsorbed in the surface layer of the spray solution. When the inactive portion is similar to or soluble in the wax, its adsorption at the leaf-spray interface reduces the interfacial tension and

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Freundlich (26, cited 66, p. 39) points out that a liquid may not wet the surface of some solids owing to its inability to dissolve the surface layer of moist air adsorbed on them, and sometimes the wetting power of a liquid (saponin, proteids) is higher than would be expected, due to an exceptional power of surface concentration (capillary adsorption) manifested by a superficial viscosity first observed by Plateau (76) and later by Vermorel and Dantony (91). Donnan (21) and Hillyer (43, p. 524) have shown that a soap solution acts as an emulsifier by virtue of its low interfacial tension. Ruth and Kelly (82) claim that direct impact and drenching favor the formation of a film. Harkins, Brown and Davies (37), Harkins, Davies and Clark (38) and Langmuir (51) treat various phases of interfacial tension, influence of the size and shape of the molecule, active and inactive portions, orientation, etc. Moore (64), Nuttall (66) and Taylor (88) present a review of the subject and its present status.

Substances Employed.

The substances that have been used by different investigators to increase wetting and spreading include substantially all those that were employed in this Station for increasing suspension (Sec. 2) and in addition emulsions, creosote, some phenol derivatives and several of the higher alcohols. There is apparently a clear line of demarcation between wetting, spreading and distribution and adhesiveness and yet the two issues are sometimes confused. Furthermore, the results are generally based on the character of the wetting and the visible deposit on the foliage—a matter of personal judgment, however careful the observations. Most of the experiments cited apply to foliage having a thin cellulose or cutinized epidermis, and those pertaining to waxy leaves and fruits are so designated. The theory that "like attracts like" may have unduly influenced practice in some instances.

Attention is called to the results of other investigators. Recent data on sugar and dextrin have been seldom noted. The use of saponin to increase spreading was probably first recommended by Gastine (32) and later by Chappaz (13) and Lafforgue (50). Cactus (Cereus) extract, containing cactine, apparently has a similar action and was found by High (42) to increase the spreading of arsenites. Irish or Pearl moss (Chondrus), so-called carrageen, was employed by Issleib (46) and, according to Stearns (86, p. 9-13), facilitates the distribution of arsenicals. Lovett (58) found that sage tea increased the spreading of arsenicals on plain but not on waxy surfaces (59). Vermorel and Dantony (94) claim that 0.05 per cent of casein increases the spreading of Bordeaux on grape vines, and Stearns (86, p. 9-13) and Smith (85) that calcium caseinate increases the spreading of lead arsenate. Some workers report casein of 0.003 to 0.03 per cent (probably with alkali) an effective spreader. David (78) employed 0.75 per cent of glue with Bordeaux but later (63) decided it was of no particular value. Lowe (60) states that glue increased the spreading of lead arsenate. Hawkins (40, p. 22-25) found that 0.50 per cent of glue, fish-oil soap and rosin fish-oil soap reduced the surface tension of Bordeaux 4-2-50 and their efficiency increased in the order named. Galloway (28, p. 220, 221; 29, p. 202, 203, 213; 30, p. 131), Fairchild (24) and Swingle (87) found soaps increased the wetting and spreading of copper fungicides, and Washburn (95) that 1.50 per cent of whale-oil soap increased the spreading of Paris green and apparently the adhesiveness. Trappmann (89) found soap the cheapest wetting material but unsafe to use with arsenicals. Sodium oleate and sodium resinate are occasionally suggested as substitutes. Various earths and other inorganic substances have been used but proved of little value as spreaders.

Oil emulsions, soap emulsions of creosote and saponin emulsions of creosote (32) are said to increase spreading on all surfaces but are seldom employed with copper fungicides. Pickering (74, p. 2010, 2011; 2, p. 29) recommended a stable emulsion prepared from copper sulfate, calcium hydroxide and a high-boiling distillate, but data relative to its efficiency are not available. Winston, Bowman and Yothers (97) claim that 1 per cent of oil emulsion with Bordeaux 3-3-50 increased spreading on citrus. Moore (64, p. 18, 19) found beechwood and coal tar creosotes, phenol derivatives, such as carvacrol, eugenol and xylenols, and amyl and benzyl alcohols excellent for waxy surfaces.

Among the points that should be considered are compatibility with the fungicide, effectiveness in wetting and spreading, ease of preparation and cost. The evidence presented is drawn from special experiments with basic copper sulfate by Dr. E. F. Guba of the Market Garden Field Station at Waltham. He employed cucumbers and tomatoes in the greenhouse and cucumbers and celery in the field. The amount of substance added is reported on the basis of the spray—0.10 per cent is equivalent to 3.8 grams (0.13 oz.) to an American gallon, or 188.5 grams (6.65 oz.) to the barrel. He found that basic copper sulfate had rather poor wetting and spreading properties as compared with Bordeaux 4-4-50. With

0.10 per cent of sugar or 0.05 to 0.15 per cent of dextrin no improvement was observed. With 0.10 to 0.21 per cent of Tekoe flour a slight increase was reported and with 0.10 per cent of wheat flour "fair" spreading obtained. Starchy products have to be dispersed (gelatinized) before use, and in the case of flour and its by-products the addition of dilute caustic soda or potash probably increases their effectiveness by dissolving the proteids. Alkali was not employed in this experiment. With 0.05 to 0.15 per cent of gum arabic (Acacia) poor wetting and spreading were secured, which probably holds true for tragacanth.

Soapbark (Quillaja) extract and 0.03 to 0.10 per cent of technical saponin gave excellent spreading. Guba did not commend either gelatin or soluble albumen at the rate of 0.05 to 0.10 per cent but obtained excellent wetting and spreading with the same amount of glue. Gelatine and glue have to be dispersed in warm water, and a high-grade animal glue requires aging to develop its maximum efficiency as an adhesive. Possibly a low-grade animal glue which is more readily soluble or a fish glue might serve in this connection, although there is no evidence to that effect. Albumen, casein, dried blood, egg-powder and other nitrogenous substances require a small amount of alkali for proper dispersion. With 0.10 per cent of skim milk powder, good spreading was secured; but an equivalent amount, in dry matter, of semi-solid buttermilk proved less satisfactory and about equal to Tekoe flour. No alkali was added. With 0.10 to 0.13 per cent of calcium caseinate, a commercial preparation, excellent wetting and spreading were obtained. Laucksite, a soy-bean—fish-oil adhesive, proved less satisfactory. With 0.10 per cent of Castile soap, 0.10 per cent of Ivory soap and 0.05 to 0.75 per cent of rosin fish-oil soap, excellent spreading was secured—even better in the case of rosin fish-oil soap than with calcium caseinate. The resulting curdy precipitate on standing was objectionable with all soaps. Soaps are effective on both plain and waxy surfaces, although the amount may have to be increased to 0.20 to 0.25 per cent in the latter case. With 0.10 per cent of Wilkinite poor wetting and spreading were obtained.

In Guba's experiments saponin, glue, calcium caseinate and soap proved the most efficient of the substances tested, although wheat flour deserves mention. Some albuminous substances may react with the copper to form soluble compounds as previously shown (Sec. 1). Soap mixtures should be applied immediately after preparation to avoid the formation of a curdy precipitate. The cost of most of the supplementary products is negligible as compared with labor, but the reduction in amount of infection due to better distribution of the fungicide is not always appreciable according to our Station observers. This may not hold equally true on waxy surfaces.

4. To increase adhesiveness by forming more resistant deposits.

The degree of dispersion and uniformity of distribution are important factors in the adhesiveness of copper fungicides. An increase in spreading assures better distribution and generally a more persistent and protective deposit. Many investigators endeavor to increase adherence still further by the formation of more resistant deposits. If carried too far, however, the fungicidal action may be impaired and the physiological activity of the plant reduced materially by the impenetrable coating on the surface which is particularly noticeable in the case of certain emulsions.

Numerous investigators have contributed to this phase of the subject. Perret (71) employed 0.20 per cent molasses with Burgundy mixture; Galloway (27, p. 10, 21), molasses with Burgundy on grapes; Gastine (31), molasses with Bordeaux; and Perraud (69), molasses with Bordeaux on grapes and evidently considered it beneficial. On the other hand, Girard (34) used 2 per cent molasses with Bordeaux on potatoes, Guillon and Gouirand (35, 36), 1 per cent molasses with Bordeaux on grapes; Lavergne (52), sugar with Bordeaux; Kelhofer (48), 0.10 per cent sugar with Bordeaux and Burgundy mixtures; and Butler and Smith (10, p. 441), 0.10 per cent sugar with Bordeaux and concluded that molasses and sugar were comparatively inefficient or reduced adherence. Kelhofer (48) found that 0.10 per cent sugar increased the adhesiveness of both neutral and basic copper acetates, especially the latter. Fernald (25, p. 6) recommended glucose or molasses as a sticker for lead arsenate. Lowe (60) found glucose inefficient with lead arsenate. Perraud (69) claimed that dextrin and starch with Bordeaux were of no value, but Patrigeon (68) stated that 0.50 per cent of dextrin increased adhesiveness. Parker (67) found that flour increased both spreading and adhesiveness of lead arsenate, and Headlee (41, p. 294) that flour doubled the adherence. Perraud (69) found gum tragacanth fairly efficient.

Stearns (86, p. 9-13) reported that Irish moss (extract) increased the adherence of arsenicals. Guillon and Gouirand (35, 36) found 0.30 per cent of gelatine with "acid" Bordeaux of little or no value, and Butler and Smith (10, p. 437, 442) obtained similar results from casein with Bordeaux 4-4-50. Butler and Smith (11, p. 284-286) found, however, that 0.05 per cent of gelatine increased materially the adhesiveness of neutral and basic copper acetates. Vermorel and Dantony (93) had previously noted this effect and also claimed (92) that 2 per cent of casein renders all alkaline copper sprays adherent to grape vines, recommended (93) casein for Bordeaux and showed (94) that 0.05 per cent increased the adherence of Bordeaux to grape vines. Chauzit (15), Degrully (19) and the Iowa Experiment Station (45) considered casein effective with Bordeaux; and Lecomte (53), that 2 per cent of milk increased the adhesiveness of Bordeaux 8-4-50. Headlee (41, p. 294) found that calcium caseinate or powdered skim milk more than doubled the adherence of lead arsenate. Perraud (69) claimed egg powder and dried blood inefficient with Bordeaux, while Cazeneuve (12) reported egg white and dried blood very effective. Galloway (27, p. 10, 21) secured good results from glue with Burgundy (although 3.5 per cent proved injurious); and Perrand (69, 70), from glue with Bordeaux. Lowe (60) increased the adherence of lead arsenate with glue; and Stearns (86, p. 9-13), that of arsenicals with calcium caseinate. Lees (54) employed glue, flour and a mixture (55) of whiting, glue and potassium bichromate as stickers for cover washes. Neuweiler (65) claimed that 0.01 to 0.20 per cent of tannin increased the adherence of Bordeaux. Perraud (69) observed that rosin increased the adhesiveness of Burgundy; Ravaz and Bonnet (80), that resin slightly increased the adherence of Bordeaux; Sirrine (84), that a resin-lime mixture increased the adhesiveness of Bordeaux and Paris green to cabbage and cauliflower; and Gillett (33), that sodium resinate increased the adhesiveness of arsenites. Guillon and Gouirand (35, 36) found that 3 per cent of soap with Burgundy and 2 per cent with Bordeaux increased adhesiveness; Perraud (69), that 3 per cent of soap increased the adhesiveness of Bordeaux; Chuard and Porchet (14), that soap increased adherence on grapes; Shear (83), that rosin fish-oil soap increased the adhesiveness of Bordeaux on cranberries; Hawkins (39, 40 p. 19), that rosin fish-oil soap increased the adherence of Bordeaux on grape leaves, and that 0.50 per cent of fish-oil soap and rosin fish-oil soap increased the adherence of Bordeaux 4-2-50 on grape berries (40, p. 25); and Washburn (95), that 1.50 per cent of whale-oil soap or soft soap increased both spreading and adhesiveness of Paris green. Dye and Newhall (23) found that 2 pounds of resin-fish-oil soap in 50 gallons increased the adhesiveness of Bordeaux 5-5-50 to celery and possibly served as a spreader. Berger (4) claimed that 3 per cent of linseed oil increased the sticking of Bordeaux 8-8-50: the Iowa Experiment Station (45), that small amounts seemed effective with Bordeaux; and Hood (44), that 1 pint of linseed or fish oil in 50 gallons increased substantially the adherence of lead arsenate. Degrully (20) advocated silicic sol as a sticker for copper sprays.

The work of Guba of this Station with basic copper sulfate was conducted largely in the greenhouse on cucumbers and tomatoes with artificial rain, but also in the field with cucumbers and celery. In many instances the copper on a given area of leaf surface was determined in the laboratory by electrical deposition and calculated to 100 square inches, although substantially all of the deposit was on the upper surface. In some cases there was considerable variation in the amount of copper in duplicate applications due to unequal distribution, the impossibility of uniform washing, the small number of leaves available for analysis from greenhouse tests, loss in ashing, etc.; nevertheless the results shown in Table 2 are helpful.

Table 2.—Effect of Adhesives on Spray Residue.

Fungicide and Adhesive	Copper on Leaf Surface per 100 Square Inches		Adherence Observed after Washing (Guba)
	Deposited	After Washing	
	Grams	*Grams*	
Bordeaux mixture 4-4-50	0.0094	0.0068*	excellent
Basic copper sulfate (same concentration as Bordeaux):			
without adhesive	0.0091	0.0045*	poor to fair
with—sugar 0.10%	0.0098	0.0030	poor
wheat flour (patent) 0.10%	0.0113	0.0056	good
Tekoe flour 0.10%	....	0.0042	fair to good
Tekoe flour 0.21%	....	0.0046	fair to good
gum arabic 0.10%	0.0028*	0.0040	poor to fair
saponin 0.10%	....	0.0010	poor
glue 0.10%	0.0077	0.0037	fair to good
Laucksite 0.10%	0.0105	0.0056	....
skim milk powder 0.10%	....	0.0013	poor
semi-solid buttermilk 0.10%	....	0.0026	fair to good
calcium caseinate 0.10%	0.0071	0.0028	....
Castile soap 0.10%	0.0092	0.0050	....
rosin fish-oil soap 0.10%	0.0067	0.0032	fair
Wilkinite 0.10%	0.0099	0.0029	....
Average	0.0091	0.0035	....

*Excluded from average.

Bordeaux 4-4-50 was employed as a standard, and basic copper sulfate without adhesive as a check. The amount of copper in the unwashed spray residue was fairly constant and averaged 0.0091 grams to 100 square inches. Basic copper sulfate with and without adhesive deposited substantially as much copper as Bordeaux. The results after washing are less dependable, however, as washing was a factor impossible to control under the conditions of the experiment. Bordeaux is fairly conspicuous on the leaf surface due to the excess lime (whitewash). Guba reported the retention as "excellent", which was confirmed by the copper content. Basic copper sulfate is less visible. The adherence was reported as "poor to fair", although the copper was two-thirds that of Bordeaux. Admixtures with flour, Wilkinite and other substances increased the visibility of the residue. Sugar with basic copper sulfate was "poor" and actually reduced adherence, probably due to the formation of copper saccharate which is removed by washing and carried more or less of the insoluble portion of the fungicide. Guba employed 0.05 per cent of dextrin with basic sulfate on cucumbers and celery in the field but did not observe any increase in either spreading or adhesiveness. Flour proved a "good" adhesive, and Tekoe "fair to good" at both concentrations. The efficiency of both products might have been increased by the addition of a small amount of alkali to disperse the albuminous compounds. Gum arabic was "poor to fair" and saponin "poor."

Glue was reported "fair to good", but was more promising in field tests than the figures indicate. Laucksite, a soy-bean-fish-oil adhesive, was effective but disliked and is not obtainable in eastern markets. Skim milk powder was "poor"; semi-solid buttermilk, reported "fair to good", was ineffective; and calcium caseinate of similar character. Better dispersion might have proved of advantage. Castile soap increased adherence. Ivory soap was "fair to good"; and rosin fish-oil soap, reported "fair", was of little value as an adhesive, although 0.75 per cent (1 ounce per gallon) in field tests proved superior to 0.10 per cent glue. Wilkinite increased visibility but not adhesiveness.

Linseed oil, at the rate of 0.10 per cent, with basic copper sulfate has been employed in field experiments with various crops for two seasons. The oil disperses readily in the spray and seems to have value as a sticker. Its use on fruits has been endorsed by some members of the staff.

In Guba's experiments the addition of a small amount of properly dispersed flour, glue and Castile soap to basic copper sulfate, evidently increased the adherence, but whether this was due to better distribution, to the formation of more resistant deposits, or both, is difficult to say and likely to vary with the supplement employed and the character of the leaf surface. Reaction products such as copper albuminate, caseinate, oleate, palmitate, resinate, stearate and tannate are relatively insoluble in water and are generally considered of low fungicidal value, but in small amounts may increase the retention of the deposit on the leaves. Fineness, stability and water-resisting properties are factors to be noted. Various proprietary Bordeaux mixtures and copper hydroxide might profit by similar treatment. The time and labor required for the proper dispersion of the adhesive, however, is a feature that renders the process objectionable to most operators.

5. To prevent or reduce crystallization or decomposition by the addition of protectors.

Bordeaux mixture on standing loses its gelatinous character, settles, gradually acquires a purplish color, and the final, dense aggregates are said to be sphaero crystals of undetermined composition. Burgundy mixture undergoes a somewhat similar change and is converted into malachite. The incorporation of properly prepared protective substances may serve to prevent or, at least, retard crystallization and to preserve the highly dispersed character of the precipitate with its high power of suspension, excellent wetting and spreading properties and adhesiveness. The use of protectors with coarser suspensions probably act in a like manner but to a lower degree. Kelhofer (49) advised the addition of sugar to Bordeaux mixture to prevent crystallization, Butler (7, 8, 9) found 0.03 per cent of sugar effective, and Lutman (61) reported both sucrose and glucose efficient. The practice has become fairly well recognized for Bordeaux mixtures that have to be kept for several hours. Data on the subject are rather meager, as most copper fungicides are applied immediately after preparation.

6. To prevent or reduce interactions between fungicides and insecticides in combined sprays.

Generalizations on interactions involving so diversified products as are employed in disease and insect control are of questionable value. Most of the copper fungicides and of the stomach poison arsenicals in current use are relatively insoluble and fairly stable, but more or less subject to hydrolysis and readily decomposed by soluble compounds such as nicotine sulfate, soluble sulfides, soaps, etc. As a rule the arsenicals require more consideration than Bordeaux, Burgundy and other copper fungicides, as soluble compounds of arsenous and arsenic acids are extremely toxic to foliage. Lime-sulfur should never be combined with copper fungicides; but in the case of arsenicals, milk of lime, calcium caseinate and protective colloids in general may serve to retard objectionable reactions. The order of mixing has been emphasized by Robinson (81) and others. Some writers treat the subject as merely a matter of compatibles and non-compatibles.

7. To increase visibility of the deposit.

Bordeaux mixtures containing an excess of lime (whitewash) probably yield the most conspicuous deposits on the leaf surface covered of any of the copper fungicides. Several of the supplementary products serve to increase substantially the visibility of basic sulfate and similar fungicides, of which Wilkinite and wheat flour proved excellent.

Summary.

1. The efficiency of insoluble copper fungicides is dependent largely on the degree of dispersion and other physical characteristics, as determined by suspension, which is undoubtedly the simplest and most practical method of evaluation. Wetting, spreading and adhesiveness are so closely correlated and interdependent that complete differentiation is impossible.

2. So-called "soluble copper" is not a criterion of fungicidal activity, as various organic compounds produce filtrable copper, the activity of which is lower than that of soluble inorganic compounds which are readily ionized.

3. Suspension, although largely dependent on dispersion, may be increased in a measure by supplementary products. This is likewise true of wetting, spreading and adhesiveness.

4. Protectors may retard the formation of larger aggregates, crystallization, decomposition and the interactions between non-compatibles.

5. Of the various supplements tested by the Massachusetts Experiment Station, wheat flour, glue (or gelatine), soap and tannic acid are promising in that they seem to increase the efficiency of the spray in more than one aspect.

Literature Cited

1. Bain, S. W. 1902. The action of copper on leaves. Tenn. Agr. Expt. Sta. Rpt. 15, Bul. 2:17-108.
2. Bedford, Duke of, and Pickering, S. U. 1908. Emulsions. Woburn Expt. Fruit Farm Rpt. 8:18-32.
3. .... and Pickering, S. U. 1910. The action of copper in different states of combination. Woburn Expt. Fruit Farm Rpt. 11:125-129.
4. Berger, E. W. 1917. Linseed oil Bordeaux. Fla. State Hort. Soc. Proc. 30:44-47.
5. Bourcart, E. Trans. T. R. Burton. 1925. Insecticides, fungicides and weedkillers. Ed. 2, 431p., illus. London.
6. Brunnich, J. C., and Smith, F. 1914. Factors influencing efficacy and deterioration of cattle-dipping fluids. Queensland Agr. Jour. New Ser. 2:81-92.
7. Butler, O. 1914. Bordeaux mixture. 1 Physico-chemical studies. Phytopath. 4:125-180.
8. .... 1914. Notes on the preparation of Bordeaux mixture. N. H. Agr. Expt. Sta. Circ. 15.
9. .... 1923. Chemical, physical and biological properties of Bordeaux mixtures. Indus. and Engin. Chem. 15:1039-1041.
10. .... and Smith, T. O. 1919. Relative adhesiveness of the copper fungicides. Phytopath. 9:431-444.
11. .... and Smith, T. O. 1922. On the use of copper acetates as fungicides. Phytopath. 12:279-289.
12. Cazeneuve, P. 1898. La bouillie bordelaise albumineuse. Vigne France, No. 4:51-53. Rev. Vitic. 9:279-280.
13. Chappaz, G. 1913. Les bouillies mouillantes. Prog. Agr. et Vitic. 59:487-491. Bul. Agr. Algérie et Tunisie, Maroc. 19:187-191.
14. Chuard, E., and Porchet, F. 1905. L'adherence des bouillies cupriques. Rev. Vitic. 24:33-37.
15. Chauzit, J. 1913. La bouillie bordelaise mouillante et adherente. Rev. Vitic. 39:764-766.
16. Clark, J. F. 1902. On the toxic properties of some copper compounds with special reference to Bordeaux mixture. Bot. Gaz. 33:26-48.
17. Cooper, W. F., and Nuttall, W. H. 1915. The theory of wetting and the determination of the wetting power of dipping and spraying fluids containing a soap basis. Jour. Agr. Sci. [England] 7 (Pt. 2):219-239.

18. Coupin, H. 1898. Sur la toxicite des sels de cuivre a l'egard des vegetaux superieurs. Compt. Rend. Acad. Sci. [Paris] 127:400-401.

19. Degrully, L. 1921. Emploi de la casein et du lait pour rendre adherente la bouillie bordelaise. Prog. Agr. et Vitic. 75:372-373.

20. .... 1923-24. Pour augmenter le pouvoir mouillant des bouillies cupriques. Prog. Agr. et Vitic. 80:633-634; 81:83.

21. Donnan, F. G. 1899. Ueber die Natur der Seifenemulsionen. Ztschr. Phys. Chem. 31:42-49.

22. Doran, W. L. 1923. Toxicity studies with some copper fungicides. Phytopath. 13:532-542.

23. Dye, H. W., and Newhall, A. G. 1925. The control of bacterial blight of celery by spraying and dusting. N. Y. (Cornell) Agr. Expt. Sta. Bul. 429:1-30.

24. Fairchild, D. G. 1894. Experiments with fungicides to prevent leaf blight of nursery stock. Jour. Mycol. 7:338-353.

25. Fernald, C. H. 1894. A new insecticide. Arsenate of lead. Mass. (Hatch) Agr. Expt. Sta. Bul. 24:3-7.

26. Freundlich, ... 1909. Kapillarchemie. p. 176.

27. Galloway, B. T. 1892. Report on experiments made in 1891 in the treatment of plant diseases. U. S. Dept. Agr. Div. Veg. Path. Bul. 3:1-31.

28. .... 1893. Field work of the year in treating plant diseases. Rpt. Sec. Agr. 1892:216-234.

29. .... 1893. Experiments in the treatment of rusts affecting wheat and other cereals. Jour. Mycol. 7:195-226.

30. .... 1894. Some observations on new and old insecticides and their combination with fungicides. Insect Life 7:126-132.

31. Gastine, G. 1898. Les preparations cupriques et leur adherence. Bul. Mens. Off. Renseig. Agr. [France] 5:595-603.

32. .... 1911. Sur l'emploi des Saponines pour la preparation des emulsions insecticides et des liqueurs de traitements insecticides et anticryptgamiques. Compt. Rend. Acad. Sci. [Paris] 152:532-534.

33. Gillett, C. P. 1890. Experiments with arsenites. Iowa Agr. Expt. Sta. Bul. 10:401-420.

34. Girard, A. 1892. Recherches sur l'adherence aux feuilles des plantes, et notament aux feuilles de la pomme de terre, des composes cuivriques destines a combattre leurs maladies. Compt. Rend. Acad. Sci. [Paris] 114:234-236.

35. Guillon, G. M., and Gouirand, G. 1898. Sur l'adherence des bouillies cupriques utilisees pour combattre les maladies cryptogamiques de la vigne. Compt. Rend. Acad. Sci. [Paris] 127:254-256; 423-424.

36. .... and Gouirand, G. 1898. Recherches sur l'adherence des bouillies cupriques. Rev. Vitic. 10:631-635.

37. Harkins, W. D., Brown, F. E., and Davies, E. C. H. 1917. The structure of the surfaces of liquids, and solubility as related to the work done by the attraction of two liquid surfaces as they approach each other. Jour. Amer. Chem. Soc. 39 (Pt. 1):354-364.

38. .... Davies, E. C. H., and Clark, G. L. 1917. The orientation of molecules in the surfaces of liquids, the energy relations at surfaces, solubility, adsorption, emulsification, molecular association, and the effect of acids and bases on interfacial tension. Jour. Amer. Chem. Soc. 39 (Pt. 1):541-596.

39. Hawkins, L. A. 1910. Grape-spraying experiments in Michigan in 1909. U. S. Dept. Agr. Bur. Plant Ind. Circ. 65.

40. .... 1912. Some factors influencing the efficiency of Bordeaux mixture. U. S. Dept. Agr. Bur. Plant Ind. Bul. 265:1-29.

41. Headlee, T. J. 1924. Sticker for lead hydrogen arsenate. N. J. Agr Expt. Sta. Rpt. 44:293-297.

42. High, M. M. 1915. Cactus solutions as an adhesive in arsenical sprays for insects. U. S. Dept. Agr. Bul. 160.

43. Hillyer, H. W. 1903. On the cleaning power of soap. Jour. Amer. Chem. Soc. 25 (Pt. 1):511-524.

44. Hood, C. E. 1926. Fish oil, an efficient adhesive in arsenate-of-lead sprays. U. S. Dept. Agr. Bul. 1439:1-21.

45. Iowa Agricultural Experiment Station. 1924. Efficiency of "stickers" in increasing insecticidal value of Bordeaux mixtures. Iowa Agr Expt. Sta. Rpt. (June 30, 1924):39-40.

46. Issleib, ... 1914. Die Beseitigung der Insekten, welche den Wein-und Obstbau schadigen, durch Verklebung mit Hilfe von Moosschleim. Ztschr. Pflanzenkrank. 24 (Pt. 2):78-79.

47. Kahlenberg, L. and True, R. H. 1896. On the toxic action of dissolved salts and their electrolytic dissociation. Bot. Gaz. 22:81-124.

48. Kelhofer. W. 1907. Uber die Ausfuhrung und die Ergebnisse von Haft festigkeitsversuchen Kupferhaltiger Bekampfungsmittel gegen die Peronospora. Ztschr. Pflanzenkrank. 17:1-12.

49. .... 1908. Uber einige Gesichtspunkte bei der Herstellung der Bordeauxbruhe. Internatl. Phytopath. Dienst 1:65-73. Ztschr. Pflanzenkrank. 18.

50. Lafforgue, G. 1913. Les bouillies cupriques mouillantes. Vie Agr. et Rurale 3:611-614.

51. Langmuir, I. 1917. I. The constitution and fundamental properties of solids and liquids. II. Liquids. Jour. Amer. Chem. Soc. 39 (Pt. 2): 1848-1906.

52. Lavergne, G. 1896. Rapport sur le black-rot dans l'Armagnac en 1895. Bul. Min. Agr. [France] 15:285-291.

53. Lecomte, A. 1913. Contribution a la recherche d'une bonne bouillie mouillante. Rev. Vitic. 40:225-228.

54. Lees, A. H. 1915. Winter cover washes. Ann. Appl. Biol. 1:351-364.

55. .... 1916. Winter cover washes. Ann. Appl. Biol. 2:245-249.

56. Lefroy, M. H. 1915. Insecticides. Ann. Appl. Biol. 1:280-298.

57. Lodeman, E. G. 1896. The spraying of plants. 399 p., illus. New York, London.

58. Lovett, A. L. 1918. Spreaders for arsenate sprays. Jour. Econ. Ent. 11:66-69.

59. .... 1920. Insecticide investigations. Oreg. Agr. Expt. Sta. Bul. 169.

60. Lowe, V. H. 1896. Combating the cottonwood leaf beetle. N. Y. (Geneva) Agr. Expt. Sta. Rpt. 15:543-544.

61. Lutman, B. F. 1916. Some studies on Bordeaux mixture. Vt. Agr. Expt. Sta. Bul. 196:3-80.

62. Mausier, ... 1908. Principles d'apres lesquels doivent etre composes les insecticides. Bul. Soc. Agr. France 63:86-93.

63. Millardet, A., and David, E. 1886. Resultats de divers procedes de traitement sur le developpement du mildiou. Jour. Agr. Prat. 50:764-770.

64. MOORE, W. 1921. Spreading and adherence of arsenical sprays. Minn. Agr. Expt. Sta. Tech. Bul. 2:1-50.

65. NEUWEILER, E. 1926. Kartoffelspritzversuche 1916-1925. Landw. Jahrb. Schweiz 40:469-515.

66. NUTTALL, W. H. 1923. Industrial application of wetting power. Brit. Assoc. Adv. Sci. Rpt. 5, Colloidal Chemistry, [etc.] p. 38-47.

67. PARKER, W. B. 1913. Flour paste as a control for red spiders and as a spreader for contact insecticides. U. S. Dept. Agr. Bur. Ent. Circ. 166:1-5.

68. PATRIGEON, G. 1890. Revue viticole; le mildiou; necessite de le combattre; epognes des traitements; poudres et liquides; superiorite de ces derniers; solution simple, eau celeste, ammoniure de cuivre; bouillies bordelaise et a l'hydrocarbonate de cuivre, hydrocarbonate de cuivre ammoniacal. Jour. Agr. Prat. 54:700-704.

69. PERRAUD, J. 1898. Recherches sur quelques moyens permettant d'augmenter l'adherence des bouillies cupriques. Compt. Rend. Acad. Sci. [Paris] 127:876-879.

70. .... 1898. Moyens d'augmenter l'adherence des bouillies cupriques sur les raisins. Jour. Agr. Prat. 62 (Pt. 2):814-816.

71. PERRET, MICHEL. Jour. Agr. Prat., cited by Lodeman, p. 43.

72. .... Jour. Agr. Prat., cited by Lodeman, p. 133.

73. PFEFFER, W. Trans. A. J. Ewart. 1903. The physiology of plants. v. 2 (2d Ed.).

74. PICKERING, S. U. 1907. Emulsions. Trans. Chem. Soc. [London] 91 (Pt. 2):2001-2021.

75. .... 1912. Copper salts and their behavior with alkalis. Trans. Chem. Soc. [London] 101 (Pt. 1):174-192.

76. PLATEAU, ... 1873. Statique des liquides 2:261.

77. PONS, B. 1889. La bouillie bordelaise celeste; bouillie bordelaise perfectionnee. Jour. Agr. Prat. 53:865-867.

78. PRILLIEUX, ... 1885. Rapport au ministre de l'agriculture sur le traitement du mildiou dans le Medoc. Jour. Agr. Prat. 49:659-662.

79. QUINCKE, G. 1877. Ueber den Randwinkel und die Ausbreitung von Flussigkeiten auf fasten Korpern. Wied. Ann. Phys. und Chem. neue Folge 2:145-194.

80. RAVAZ, L., AND BONNET, A. 1903. Experiences sur le traitement du mildiou. Ann. Ecole Natl. Agr. Montpellier n. ser. 3:157-168.

81. ROBINSON, R. H. 1926. Sprays, their mixing and the compatibility of various combinations. Oreg. Agr. Expt. Sta. Circ. 68:1-11.

82. RUTH, W. A., AND KELLY, V. W. 1922. Recent advances in spraying. Ill. State Hort. Soc. Trans. New Ser. 56:90-103.

83. SHEAR, C. L. 1906. Cranberry spraying experiments in 1905. U. S. Dept. Agr. Bur. Plant Ind. Bul. 100.

84. SIRRINE, F. A. 1898. A spraying mixture for cauliflower and cabbage worms. N. Y. (Geneva) Agr. Expt. Sta. Bul. 144:23-46.

85. SMITH, R. H. 1922. The important orchard insects of Idaho, and their control. Idaho Agr. Expt. Sta. Circ. 23:1-8.

86. STEARNS, L. A. 1920. Experiments on the control of the oriental fruit moth. Va. State Crop Pest Comm. Quart. Bul. 2:1-16.

87. SWINGLE, W. T. 1894. An improved method of making Bordeaux mixture. Jour. Mycol. 7:365-371.

88. TAYLOR, H. S. 1924 A treatise on physical chemistry. v. 2, chap. 20, Colloidal Chemistry, W. A. Patrick. New York.

89. Trappmann, W. 1926. Methoden zur Prufund von Pflanzenschutz-mitteln I. Benetzungsfahigkeit. Arb. Biol. Reichsanst. Land u. Forstw. 14:259-266.

90. Vermorel, V., and Dantony, E. 1910. Des principes generaux que doivent presider a l'establissement des formules insecticides. Compt. Rend. Acad. Sci. [Paris] 151:1144-1146.

91. .... and Dantony, E. 1912. Tension superficielle et pouvoir mouillant des insecticides et fongicides—Moyen de rendre mouillantes toutes les bouillies cupriques ou insecticides. Compt. Rend. Acad. Sci. [Paris] 154:1300-1302. Rev. Vitic. 37:715-716.

92. .... and Dantony, E. 1913. Les bouillies fongicides monillantes. Rev. Vitic. 39:759-760.

93. .... and Dantony, E. 1914. Bouillies mouillantes adherentes. Prog. Agr. et Vitic. (Ed. l'Est-Centre) 35:561-562.

94. .... and Dantony, E. 1919. Efficacite comparee des bouillies bordelaises ordinaries et des bouillies bordelaises caseinees pour la preservation des grappes. Prog. Agr. et Vitic. 40:350-351.

95. Washburn, F. L. 1891. Practical work with the codling moth and with a combined insecticide and fungicide. Oreg. Agr. Expt. Sta. Bul. 10:3-22.

96. Willows, R. S., and Hatschek, E. 1915. Surface tension and surface energy and their influence on chemical phenomena. 78 p. London.

97. Winston, J. R., Bowman, J. J., and Yothers, W. W. 1923. Bordeaux-oil emulsion. U. S. Dept. Agr. Bul. 1178:1-23.

Publication of this document approved by the
Commission on Administration and Finance

2 M-6-'29. No. 5972.

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 253 July, 1929

Milk Substitutes for Calves

By J. B. Lindsey and J. G. Archibald

The production of milk for near-by consumption is the principal industry of Massachusetts dairymen. The maintaining of the herd is an ever-present problem. Some farmers prefer to purchase mature milkers and others to rear calves from their own cows. This Station has been studying the most economical and satisfactory method of growing the calf until four months of age, and presents the results of its findings in this bulletin.

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AGRICULTURAL EXPERIMENT STATION,
AMHERST, MASS.

MILK SUBSTITUTES FOR CALVES

By J. B. Lindsey, Research Professor, and J. G. Archibald, Assistant Research Professor, of Chemistry[1]

Introduction

The need for satisfactory milk substitutes for raising calves in the market milk producing sections of New England led this Station to investigate the problem early in its history. The need has become more acute with the passing of the years and the great development of the fluid milk trade, so that greater effort has been made at this and other stations to solve the problem.

The earlier work carried on by this Station was devoted to attempts to formulate a satisfactory calf meal.[2] Many combinations of the various grains and their by-products were tried, and some were developed which gave fairly satisfactory growth. None of these, however, approached skim milk in the production of growth, and since 1924 the studies have been confined largely to various methods of feeding skim milk powder and buttermilk powder, alone and in combination with other feeds. As these are milk products, in the strict sense of the word they are not milk substitutes; but since the problem is one of local rather than general shortage of skim milk, and since they solve transportation and storage problems inseparable from fluid milk, they are to that extent substitutes for it. Large tonnages of these materials are produced in the butter making and cream selling sections of the country, and the prevailing prices for them have been and still are reasonable (9 to 10 cents a pound).

The following pages describe in detail methods used and results secured in feeding the milk powders. A summary of the work appears in Table 1.

Description of General Method of Feeding and Management

Practically all calves used in this work have been Holsteins, the majority of them being the natural increase of the station herd, although some were bought outside. At least five calves have been used for each separate experiment.

The calves in the station herd are left with the dams from 24 to 48 hours, depending on the vigor of the calf. At the end of that time they are removed and taught to drink whole milk from a pail. Occasionally if the dam is a Jersey and known to give very rich milk, the colostrum is milked out and some of it is given to the calf from a pail. This obviates the possibility of gorging and indigestion which is sometimes seen in calves from high testing cows. Calves bought outside are secured as soon as possible after they are dropped, the average age being three to four days.

Whole milk only, of rather low fat content, is fed for the first week, usually not more than six quarts daily, although occasionally with large and vigorous calves as many as eight quarts have been fed. The process of weaning from whole milk is begun at from one week to ten days of age, one quart of the whole milk being withheld and a quart of liquid made with warm water and the material in question given in place of it. This substitution is gradually increased (usually a quart at a time every second day) until the calf is getting only two quarts of whole milk, the balance being the substitute. The amount of liquid fed is increased gradually until at three weeks of age or thereabouts the calf is getting nine quarts daily. Two quarts of whole milk are fed daily until four weeks of age, and one quart daily until six weeks of age, at which time the process of weaning from whole milk is completed. Except in some very recent experiments, liquid feeding has been continued until four months of age.

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[1] Acknowledgment is made here of the services of J. R. Alcock, foreman at the station barn, who had immediate charge of the work, and whose faithful attention to details contributed to the success of the experiments.

[2] For accounts of this work with calf meals, see Mass. Agr. Expt. Sta. Buls. 164 and 223.

The calves are taught to eat good quality rowen and a dry grain mixture as early as possible. With the rowen this is done by keeping a small handful in a manger before them all the time, at first removing each day what they do not clean up, so that it will not become stale. It is surprising how early they will nibble at it and relish it if care is used not to give them too much. The grain is rubbed on their noses or placed in the bottom of the pail when they finish drinking, and as soon as they acquire a taste for it a little is kept before them constantly. The mixture which has been fed in connection with this work is composed of:

Ground oats	30 lbs.
Red dog flour	30 "
Corn meal	25 "
Linseed meal	15 "
Total	100 lbs.

Half a pound of salt is added to each 100 pounds of the grain. This mixture contains approximately 17 per cent of protein, 5 per cent of fat and not more than 6 per cent of fiber.

The object *in all of the trials* was to encourage the calves to eat as much rowen as possible and of the grain mixture up to 3 pounds daily. Naturally when a full liquid diet was continued until 4 months of age the consumption was less than when liquid was supplied in a restricted amount.

The experimental feeding period is continued to the end of the fourth month, at which time the calves are gradually weaned entirely from pail feeding, a process which takes some two weeks or more. Some feeders prefer to continue feeding liquids until the calf is six months old. If an extra fine calf is wanted this longer period may be justified, but it adds considerably to the cost of raising.

The calves are fed three times a day at regular feeding hours, and the liquid is always fed warm, at about body temperature. The amount of skim milk powder or buttermilk powder used in making the liquid is 3½ ounces to one quart of water or, to express it in another way, one pound to 4½ quarts of water. This proportion results in a liquid with approximately the same content of dissolved or suspended solids as the original skim milk. A richer liquid than this is apt to cause digestive trouble, while if it is made too dilute the calves will not make satisfactory growth.

The above statements can serve only as a general guide. Calves vary so in their appetites and in their ability to stand changes in feed that the feeder's own good judgment must be exercised at all times. In this work the progress of the calves has been followed by weighing them each week and adjusting their ration accordingly.

Detailed Data of Experiments

Group 1. Liquid Skim Milk plus Grain and Rowen

Five calves were fed on skim milk in order to have a standard with which to compare the other materials. The average amount of skim milk fed to each calf in this group for the four-month period was 1091 quarts. They made a daily gain of 1.75 pounds, and consumed 236 pounds of dry matter for every 100 pounds of gain. They were very thrifty looking calves at the finish. Where skim milk can be obtained for not more than two cents per quart, calf rearing, insofar as an economical and satisfactory food is concerned, ceases to be a problem. Because of the low fat content of the skim milk, it is well to continue to feed with it a quart of whole milk daily up to the end of the sixth week. After that the fat can be more economically supplied in the grain mixture. Yellow hominy is a very good source of fat, also either standard wheat middlings or flour middlings. Linseed meal is high in fat but contains rather too much protein to be fed in any considerable quantity with skim milk or other milk products.

Group 2. Skim Milk Powder plus Grain and Rowen

There are two general classes of skim milk powder on the market: that manufactured by the "spray dried" process, and that manufactured by the "drum dried" or "roller" process. Six calves were fed on each kind. Those fed on "spray dried" powder made an average daily gain of 1.43 pounds, and consumed 276 pounds of dry matter for each 100 pounds of gain. Those fed on "drum dried" powder made an average daily gain of 1.41 pounds and consumed 312 pounds of dry matter for every 100 pounds of gain. Although they did not make as good growth as did those fed on liquid skim milk, all these calves were thrifty and hearty through the whole four-months period, being entirely free from digestive disturbances.

Skim milk powder has the same nutritive characteristics as the skim milk from which it is made, viz., high protein and low fat with a narrow nutritive ratio. When it is fed, the fat content of the ration should be increased by some such means as was suggested in the previous section on liquid skim milk.

Group 3. Skim Milk Powder in Limited Amount, plus Grain and Rowen

The animals in the preceding group were given a full liquid diet (9 quarts daily after the first 2 to 3 weeks) up to the end of the fourth month. Although excellent growth was obtained, skim milk powder was advancing in price, and the economy of feeding so much of it was thought to be doubtful. It was therefore decided to feed a group of calves on a somewhat smaller allowance. The procedure followed was to cut the amount of liquid at the end of the second month from nine quarts to six quarts daily, and to make a further reduction to three quarts daily at the end of the third month. At the same time the calves were encouraged to eat more liberally of dry grain and rowen. The six calves raised by this method made an average daily gain of 1.37 pounds and consumed 279 pounds of dry matter for each 100 pounds of gain. In other words they did almost as well as those that had received the full liquid feed up to four months of age, and the cost was somewhat lessened. The decreased cost was due largely to the much lower cost of the extra rowen they ate. It is interesting to note that of their own choice they compensated for the cut in liquid feed by consuming about 100 pounds more rowen per head (see Table 2). They ate almost the same amount of grain that those on full liquid feed had eaten. The average amount of skim milk powder consumed per calf up to four months of age was 123 pounds by this system, whereas in the "full feed" method it was 255 pounds. The "drum dried" skim milk powder mixes more readily with warm water and is less liable to become caked on standing than the "spray dried." For these reasons and because it was a little cheaper, it was used in feeding this and the next two groups.

Group 4. Skim Milk Powder with Red Dog Flour and Yellow Hominy, plus Dry Grain and Rowen

The objection has been raised that calves fed on skim milk or skim milk powder, although they grow well, have a tendency to be thin. This condition has not been noted at this Station, but there is good foundation for the belief that it does occur. Where it is observed it is due probably to too narrow a ration; i.e., too much protein in proportion to carbohydrates and fat, a condition resulting from too much skim milk and too little grain in the ration of calves, especially after the first month. During the first few weeks of the calf's life skim milk is very nearly an ideal diet, but as it grows older its need for carbohydrates increases relatively, and its need for protein decreases relatively although not in actual amount. Starchy feeds like hominy or flour middlings supply the carbohydrate and tend to restore the balance which has been upset by removal of the fat from the milk. The difficulty, however, is to get young calves to eat sufficient grain in the dry form to bring about the optimum balance. It is true that they will nibble at it when two or three weeks old, but they do not ordinarily eat any great quantity.

To overcome this difficulty the plan of mixing grain with their liquid feed was adopted. A mixture was formulated consisting of equal parts of red dog flour (flour middlings) and yellow hominy feed. Skim milk powder was mixed up as usual at feeding time, except that 3 ounces of powder per quart of water were used instead of 3½ ounces. To the liquid milk made from the powder was added half as much of the red dog-hominy mixture as it contained of skim milk powder, viz., 1½ ounces per quart. During the last month of the experiment the amount of red dog-hominy was increased to 3 ounces per quart of water. Two groups of calves were fed on this material; for one group of six it was partially cooked before feeding, the idea being that the cooking might render the starchy grain more digestible; the other group of five received it uncooked, the only precaution taken being to keep the mixture agitated while the calf was drinking so as to prevent the grain from settling out. No trouble was experienced in getting the calves to drink such a mixture; in fact they had the most vigorous appetites of any calves under test. The average daily gain per calf was 1.61 pounds when the gruel was cooked and 1.70 pounds for those fed uncooked gruel. The group receiving cooked gruel consumed 248 pounds of dry matter for each 100 pounds of gain; those receiving it uncooked consumed 253 pounds of dry matter for each 100 pounds of gain. It would seem from these results that there was no advantage in cooking the mixture.

The uncooked mixture proved quite superior to skim milk powder fed alone, and the growth produced very closely approached that produced in the control lot by liquid skim milk. The calves were the smoothest, best fleshed lot that have been raised at this Station in many years. It is interesting to note the extra consumption of grain brought about by this method of feeding. The average amount of grain which these calves consumed up to four months of age (including what they ate in dry form) was 212 pounds as compared with 104 pounds in those groups where grain was fed in dry form only. The average amount of skim milk powder saved by introducing the red dog-hominy mixture into the liquid was 92 pounds per calf, so that a considerable monetary saving was effected. It is possible that an even greater saving might have been effected had the same procedure been followed with a group fed the limited amount of skim milk powder.

The reason for using hominy instead of corn meal was because of its somewhat higher fat content. Yellow corn meal could be substituted if the hominy were unavailable.

Group 5. Buttermilk Powder plus Grain and Rowen

This is a common commercial article which at times may compete in the market with skim milk powder. Very little experimental work on its value for calves had been carried on, so it was included in these investigations. It was fed in the same manner and at the same rate as the skim milk powder had been, viz., 3½ ounces to a quart of warm water, and 9 quarts daily up to four months of age.

Six calves raised on it made an average daily gain of 1.64 pounds and consumed 271 pounds of dry matter for each 100 pounds of gain. This is a somewhat better growth record than that of the corresponding group of calves fed on a full feed of skim milk powder. Our experience with the material, however. was that it had two disadvantages which the skim milk powder did not have: (1) it was harder to get the calves started on it, and consequently growth was rather slow at first; (2) it had a tendency to be laxative, some of the calves scouring quite badly. Despite these drawbacks, after the first few weeks they made excellent growth as shown above, and at the finish were thrifty looking calves.

Group 6. Buttermilk Powder in Limited Amount, plus Grain and Rowen

Inasmuch as the buttermilk powder gave results, when fed on a "full feed" basis, superior to those obtained in feeding skim milk powder, it was thought advisable to feed it in limited amount also. The method followed was identical with that described in the section on "Skim Milk Powder in Limited Amount." (Group 3.)

The six calves in the group made an average daily gain of 1.10 pounds and consumed 290 pounds of dry matter for each 100 pounds of gain. This is a somewhat lower growth rate than was obtained in any other group thus far reported. The calves were not as thrifty looking as those raised on a full feed of buttermilk powder, largely because they consumed considerably less feed. It has been noted in the previous section that it was hard to get the calves started on buttermilk powder. The same was true in this group and it is thought that because of this they were not in good shape to stand the cut in liquid feed at the end of the second and third months. The average amount of buttermilk powder consumed by this group up to four months of age was 120 pounds as compared with 193 pounds in the "full fed" group. Unlike those fed on a limited amount of skim milk powder, these calves did not make up for the curtailment by consuming more grain and rowen than those on full feed. They ate less grain and about the same amount of rowen, hence their poorer growth.

Results from feeding a limited amount of powder show that skim milk powder is preferable to buttermilk powder as long as the prices of the two remain about the same.

Group 7. Diluted Whole Milk plus Grain and Rowen

Some farmers raise their calves on whole milk diluted with water, the dilution being increased as the calves grow, until just before they are weaned the liquid they are getting is largely water colored with a little milk. This method has been tried here, the general plan being as follows:

1st week—whole milk, all the calf will drink, up to 9 quarts as a maximum.
2d and 3d weeks—two parts whole milk, one part water.
4th and 5th weeks—equal parts of milk and water.
6th, 7th and 8th weeks—one part of milk to two of water.
9th, 10th, 11th and 12th weeks—one part of milk to three parts of water.
13th—17th weeks—one part of milk to four parts of water.

Five calves were raised by this system and consumed an average of 329 quarts each of whole milk. They ate much more dry grain than did any other group and more rowen than any others with the exception of those raised on a limited amount of skim milk powder. Their growth, however, was inferior to any previously reported, with the exception of Group 6, the average gain being 1.28 pounds; and they did not make as good use of their feed, consuming 304 pounds of dry matter for each 100 pounds of gain. The calves were mediocre and on the whole the experiment was not much of a success. The principal argument in favor of such a system is that it involves a minimum of labor.

A summary of the work reported in the foregoing pages appears in Tables 1 and 2. Although cost figures are given, it must be remembered that these will vary with time and place. They are, however, relative. More significant are the figures for "average daily gain" and "dry matter consumed per 100 pounds of gain." Even with these, it should be remembered that where differences between groups are very small, a repetition of the experiment might not give the same result because of the marked differences often observed between individual animals.

Table 1.—Summary of Calf Feeding Experiments.

FEED ON TRIAL	Number of calves	Weight at 4 months of age *Lbs.*	Average daily gain *Lbs.*	Dry matter consumed for 100 lbs. of gain *Lbs.*	Average food cost for 100 lbs. of gain	Food cost to 4 months of age
Liquid skim milk (control lot)	5	303	1.75	236	$16.47	$32.15
Skim milk powder (spray dried)	6	264	1.43	276	19.25	33.30
Skim milk powder (drum dried)	6	262	1.41	312	18.99	38.41
Skim milk powder (drum dried in limited amount)	6	257	1.37	279	16.98	28.23
Skim milk powder (drum dried plus red dog and hominy cooked)	6	287	1.61	248	16.35	28.40
Skim milk powder (drum dried plus red dog and hominy uncooked)	5	297	1.70	253	16.73	32.19
Buttermilk powder	6	290	1.64	271	16.52	34.94
Buttermilk powder (in limited amount)	6	224	1.10	290	18.88	28.29
Diluted whole milk	5	246	1.28	304	19.39	30.83

The food costs are based on whole milk at 7 cents a quart, skim milk at 2 cents a quart, rowen at $25 a ton, and all other feeds at prices current in January, 1929.

Table 2.—Average Amounts of Feed Consumed up to Four Months of Age by the Calves in These Experiments.

FEED ON TRIAL	Whole milk *Qts.*	Skim milk *Qts.*	Skim milk powder *Lbs.*	Butter-milk powder *Lbs.*	Grain *Lbs.*	Rowen *Lbs.*
Liquid skim milk (control lot)	131	1091	...	...	88	196
Skim milk powder (spray dried)	80	....	250	...	79	140
Skim milk powder (drum dried)	83	....	255	...	119	163
Skim milk powder (drum dried in limited amount)	161	....	123	...	115	258
Skim milk powder (drum dried plus red dog and hominy cooked)	138	....	161	...	216	141
Skim milk powder (drum dried plus red dog and hominy uncooked)	167	....	164	...	207	170
Buttermilk powder	154	....	...	193	125	207
Buttermilk powder (in limited amount)	152	....	...	120	106	203
Diluted whole milk	329	....	...	...	166	248

When red dog and hominy were fed cooked, 129 pounds of the grain consisted of the red dog-hominy mixture; when they were fed uncooked, 114 pounds of the grain consisted of the red dog-hominy mixture. In both cases the mixture was fed as gruel.

Summary and Conclusions

In the work here reported, 51 calves have been reared on various milk products. Exclusive of [the liquid skim milk control lot, most rapid growth and best use of feed consumed were obtained with a combination of skim milk powder, red dog flour and yellow hominy, fed as a liquid.

Skim milk powder when fed in large quantities (2 pounds or more daily), especially after the second month, is too expensive. Fed alone it is unbalanced, having a nutritive ratio of about 1 to 1.5. It should be supplemented with such starchy grains as hominy, corn meal, or flour middlings. This latter statement is true also for skim milk.

Buttermilk powder has considerable value as a calf feed but is not as suitable as skim milk powder for the method now recommended of limiting the supply of milk products in the calf's ration after it is two months old.

Diluted whole milk, fed as described under Group 7, is not recommended. It produced growth below the average and the cost was higher than for other methods that produced more growth.

The method which has been the most satisfactory compromise between economy and good growth has been the feeding of skim milk powder in limited amount (Group 3). If an extra good calf is desired, it is recommended that the skim milk powder be supplemented with the red dog flour—hominy mixture.

The following general statements seem warranted:

1. Even though milk protein is very necessary, the economy of feeding any form of milk products after the fourth month is doubtful. It is believed that the supply of these in the calf's ration can be limited somewhat as early as the third month.

2. Until the calf is six weeks of age, a small amount of whole milk (1 to 2 quarts daily) is very desirable because of the fat it supplies. After that age the fat can be supplied more economically in the grain.

3. It is now known that weaning can be commenced at a much earlier age than was formerly considered proper, but the economies effected in this way may defeat their own purpose. Careful attention is being given to this phase of the subject.

4. Heavy grain feeding is unnecessary and uneconomical and may even be undesirable because it discourages the calf from eating as much roughage as it otherwise would and as is probably needed in order to develop the animal's maximum feed capacity. The amount to be fed daily until the calf is six months of age, from the standpoint both of economy and of satisfactory growth, is not definitely established, but it is believed that three pounds daily should be sufficient. Calves reared at this Station have done very well on two pounds daily until one year of age, and good cows have been raised on a maximum of three pounds daily up to the first freshening time. The roughage must be of good quality, preferably rowen, alfalfa, or early cut first crop hay. Corn silage may be fed after the first six months.

Condensed Statement of the Method at Present Recommended

At the risk of repetition, the method found to be the most satisfactory compromise between low feed cost and good growth is here repeated in condensed form.

1. Remove calf from dam in from 24 to 48 hours and teach it to drink whole milk of rather low fat content.

2. Feed six quarts of whole milk daily for the first week or ten days, at the end of which time substitute for one quart of the whole milk a like amount of liquid made of warm water to which is added 3½ ounces of the dried skim milk.

3. Increase this substitution every other day by adding another quart of the prepared liquid and removing a like amount of whole milk, until the calf is getting only two quarts of whole milk daily, with a maximum of nine quarts of total liquid.

4. Feed daily a minimum of two quarts of whole milk until the calf is four weeks old, and one quart from four to six weeks old, after which time the feeding of whole milk should be discontinued. (The small amount of whole milk is recommended for the beneficial effect of its fat. It may not be necessary, but is desirable.)

5. Teach the calves to eat a good quality of rowen and a dry grain mixture as early as possible. This can be done by keeping a small quantity before them all the time, removing each day, at first, what they do not consume. Rub the grain on their noses or place a little in the bottom of the pail after they have finished drinking, and keep a small amount before them constantly. A grain mixture which has proved satisfactory is composed of:

Ground oats	30 lbs.
Red dog flour	30 “
Corn meal	25 “
Linseed meal	15 “
Total	100 lbs.

Half a pound of salt is added to each 100 pounds of the grain.

6. Reduce the liquid, at the end of the second month, from nine to six quarts daily, and at the end of the third month, to three quarts daily, encouraging the calves to eat liberally of the roughage together with reasonable amounts of grain.

7. Wean the calves entirely from liquid feeding at the end of the fourth month, which takes a week or more. In case an extra fine looking calf is wanted, the feeding of some liquid can be continued until six months of age.

8. Feed the calf three times daily at as regular intervals as possible, and be sure that the pail and other utensils are scrupulously clean.

9. See that the calf has a plentiful supply of clean pure water available at all times.

Publication of this document approved by the Commission on Administration and Finance.
4M-9-'29. No. 6679.

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 254 June, 1929

The Preparation and Effectiveness of Basic Copper Sulfate as a Fungicide

By E. B. Holland, C. O. Dunbar, G. M. Gilligan and W. L. Doran

Copper fungicides have been a subject for investigation during the past few years. The work comprises a study of chemical composition, physical characteristics and general effectiveness in field work, together with the use of various supplementary products. The main objective was the preparation of a Bordeaux substitute that could be readily suspended in water and used as a spray, or mixed with a free-flowing carrier and applied as a dust. The product must give practical control of disease but not necessarily equal to a highly dispersed Bordeaux of the same copper content. The advantages of such a product in the saving of time, labor and equipment in preparation, and the gain in uniformity and stability of the spray mixture are evident. Since basic sulfates are generally considered preferable to basic carbonates, attention has been directed largely to them.

Requests for Bulletins should be addressed to the

AGRICULTURAL EXPERIMENT STATION,

AMHERST, MASS.

THE PREPARATION AND EFFECTIVENESS OF BASIC COPPER SULFATE AS A FUNGICIDE

By E. B. Holland, Research Professor of Chemistry, C. O. Dunbar and
G. M. Gilligan, Research Assistants in Chemistry, and
W. L. Doran, Research Professor of Botany

Basic copper sulfates are insoluble copper compounds resulting from the action of alkali or alkaline earth hydroxides or carbonates, short of saturation upon copper sulfate, although other precipitants are occasionally employed. The reaction has been studied by numerous chemists as shown in a previous paper (6, p. 741, 742)[1], but the lack of agreement, as a whole, tended to indicate the production of mixtures rather than a definite compound. When, however, the amount of precipitant was sufficient for complete precipitation of the copper, or nearly so, tribasic sulfate, $4CuO.SO_3.4H_2O$, was frequently obtained. Proust (12, p. 34) prepared the compound with fixed alkalies; Kane (7, p. 270), with insufficient ammonia or potassium hydroxide; Smith (15, p. 498), with insufficient fixed alkalies and with sodium carbonate; Vogel and Reischauer (16), with ammonia; Field (5, p. 124), with insufficient fixed alkalies; and Pickering (10, p. 1982; 11, p. 1855), with fixed alkalies and with alkaline earths. More recently Bell and Taber (1, p. 173) and Young and Stearn (18, p. 1951, 1952) failed to obtain a definite salt by the phase rule, and Williamson (17, p. 790) secured unsatisfactory results but substantially the tribasic. Britton (3, p. 2152, 2153) by an electrometric determination with an oxygen electrode obtained a sodium hydroxide equivalent of 1.47 for copper sulfate which would indicate approximately $4CuO.SO_3$. The alkali was added slowly with thorough agitation in order to secure the formation of an amorphous precipitate. With a copper electrode Britton (4, p. 2798) obtained an equivalent of 1.50 and by phase rule studies at 25° (4, p. 2800–2802) established a formula of $4CuO.SO_3.4H_2O$. Bell and Murphy (2) by varying the quantity of copper sulfate with a given amount of copper oxide obtained in 8 hours at 100°C a neutral solution and the same basic sulfate. The results of Kruger (8) and Sabatier (14) tend to confirm the formula. The minerals brochantite and langite are said to be tribasic sulfates with three and four molecules of water respectively. Smith (15) obtained tetrabasic sulfate ($5CuO.SO_3.6H_2O$) short of alkalinity; and Pickering (10, p. 1982; 11, p. 1855), by adding alkali or alkaline earth hydroxide sufficient for initial alkalinity (1.60 mols). Nelson (9, p. 1189) obtained a basic sulfate of $7CuO.2SO_3$ previously reported by Proust (12, p. 34).

Preparation of Basic Copper Sulfate

With the exception of the preliminary experiments carbonates have been used as precipitants in the Station laboratory in preference to the hydroxides. The carbon dioxide evolved in the reaction prevents decomposition (blackening) in a measure, and the leavening effect of the gas seems to improve the physical condition of the resulting product. Precipitated calcium carbonate ($CaCO_3$), precipitated basic magnesium carbonate ($4MgCO_3.Mg(OH)_2.5H_2O$) and sodium carbonate (Na_2CO_3) have been employed for the purpose. The following commercial grades of precipitated calcium and magnesium carbonates are available according to the distributor:

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[1] Reference is made by number to Literature Cited, p. 148.

	Cubic Inches in 1 Pound		
Material	Light	Medium	Heavy
Calcium carbonate	91	72	47
Basic magnesium carbonate	144	..	64

The light grades were employed as presumably offering greater surface area. The fine ground crystalline forms are cheaper but more resistant and less satisfactory. The solubility of both carbonates is low. Sodium carbonate, on the other hand, is readily soluble, and the crystalline sal soda with 10 molecules of water is as serviceable as the anhydrous and monohydrated forms. Soda ash might also be included if free from caustic alkali. Sodium carbonate is the least expensive, followed by precipitated calcium carbonate and basic magnesium carbonate. The cost, however, as with many other chemicals is largely dependent on the amount purchased, size and kind of containers.

The plan of operation adopted was based on complete precipitation of the copper with a minimum of precipitant. Pickering had shown previously that 1 mol of copper sulfate required 0.75 mol of a divalent hydroxide. In the case of carbonates 0.80 mol was invariably found necessary under the conditions employed. The following tentative reactions are offered:

Tribasic copper sulfate

$$4CuSO_4 5H_2O + 3.2CaCO_3 = 4CuO.SO_3.4H_2O + 3CaSO_4 2H_2O + 0.2CaH_2(CO_3)_2 + 2.80CO_2 + 9.80H_2O$$

$$4CuSO_4 5H_2O + 0.64\,(4MgCO_3.Mg(OH)_2.5H_2O) = 4CuO.SO_3.4H_2O + 3MgSO_4 + 0.2MgH_2(CO_3)_2 + 2.16CO_2 + 19.64H_2O$$

$$4CuSO_4 5H_2O + 3.2Na_2CO_3 = 4CuO.SO_3.4H_2O + 3Na_2SO_4 + 0.4NaHCO_3 + 2.80\,CO_2 + 15.80H_2O$$

Tetrabasic copper sulfate

$$5CuSO_4 5H_2O + 4CaCO_3 = 5CuO.SO_3.6H_2O + 4CaSO_4 2H_2O + 4CO_2 + 11H_2O$$

$$5CuSO_4 5H_2O + .8(4MgCO_3.Mg(OH)_2.5H_2O) = 5CuO.SO_3.6H_2O + 4MgSO_4 + 3.2CO_2 + 29.80H_2O$$

$$5CuSO_4 5H_2O + 4Na_2CO_3 = 5CuO.SO_3.6H_2O + 4Na_2SO_4 + 4CO_2 + 19H_2O$$

1 part by weight of $CuSO_4.5H_2O$ requires:
0.32059 $CaCO_3$
0.31120 $4MgCO_3.Mg(OH)_2.5H_2O$
0.33957 Na_2CO_3

The amount of precipitant found necessary would point toward the formation of tetrabasic sulfate (see Pickering), but as the amount of copper in the tri- and tetrabasic sulfates with 4 and 6 molecules of water respectively is 54.055 and 54.240 per cent, differentiation has to be based largely on the sulfuric acid content 17.020 and 13.663 per cent SO_3. The analyses (page 127) of laboratory samples, prepared under conditions far short of theoretical control, would seem to indicate, however, that principally tribasic sulfate was formed together with more or less hydroxide when excess precipitant was employed or the mixing was inadequate. The 0.10 mol of precipitant (univalent) that did not react may represent the dilution at which the ionized sulfuric acid could not decompose the carbonates.

With the insoluble carbonates, hot dilute copper sulfate solution is run slowly into the suspended carbonate and stirred vigorously with a mechanical agitator throughout the operation; but with soluble carbonates, the carbonate is let down into the copper sulfate. The mix with insoluble carbonates should be slightly alkaline to litmus and free from soluble copper (ferrocyanide test), basic copper carbonate, and oxidation products at the completion of the reaction. A neutral to slightly acid mix with a *trace* of soluble copper is more dependable when sodium carbonate is used and likely to yield a better product. The relative concentration, temperature, rate of addition and agitation should be so coordinated as to give a basic sulfate of the best physical characteristics possible. Similar results, however, may be obtained from different correlations. Allowing the precipitate to stand before filtering affects the bulk and increases the amount of carbonate, both of which are objectionable. The presence of iron in the copper sulfate also appears to injure the physical properties. A properly prepared basic sulfate is soft, pulverulent between the fingers, and free from grit and requires no grinding except the disintegration of the cake from the filter. Subsequent air separation, however, improves the physical properties especially for dusting purposes.

Commercial Preparation

The directions recently furnished a manufacturer for the preparation of basic sulfate with calcium carbonate are practically the same as originally published except as to size of the batch and the elimination of the excess precipitant. In adapting a laboratory process to factory conditions there is likely to be some loss in quality due to the limitations imposed by economic production.

1890 grams (4.17 lbs.) of copper sulfate, substantially free from iron, in 10 gallons of solution, heated to 80°C, are added gradually to 606 grams (1.34 lbs.) of light, precipitated calcium carbonate, suspended in 5 gallons of water, at 80°C, stirred *vigorously* for 30 minutes (including the time of precipitation) at 80°C, filtered immediately, washed practically free from soluble by-products, and dried at a relatively low temperature (35-50°C) to a soft, light, bulky, free-flowing, bluish powder of fine particles having a "fair" power of suspension and adhesiveness and containing about 26.50% of metallic copper.

The above batch yields nearly 4 pounds of material. Some of the gypsum is lost in the filtrate.

The method for preparing basic copper sulfate with precipitated basic magnesium carbonate is substantially the same as with calcium carbonate except that only 588+ grams (1.30 lbs.) are required when the carbonate holds true to formula. A preliminary trial with a few grams of material is advisable, however, to establish the proper ratio. Discoloration (blackening) is more likely to occur than with calcium, probably due to the basic portion of the carbonate. The discolored portion absorbs carbon dioxide rapidly on exposure to the air and is apparently converted into a blue basic carbonate which is considered inferior to the basic sulfate. The basic sulfate is a relatively pure, soft, blue, free-flowing powder of fine amorphous particles and contains about 53 per cent of metallic copper as the by-product, magnesium sulfate, is readily removed by washing. The batch yields about 2 pounds of material.

The method for preparing basic copper sulfate with sodium carbonate differs considerably from the calcium carbonate process in the concentrations employed, in the direct addition of the precipitant to the copper sulfate, and in the control necessary to coordinate the rate of addition with the efficiency in mixing. An undue concentration of the sodium carbonate causes the formation of a deep blue precipitate or a brown precipitate that absorbs carbon dioxide from the air and becomes more or less hard and gritty.

963 grams (2.12 lbs.) of anhydrous sodium carbonate (or 1127 grams (2.48 lbs.) of $Na_2CO_3 1H_2O$, or 2600 grams (5.73 lbs.) of $Na_2CO_3 10H_2O$) in 10 gallons of solution, heated to 70°C are added gradually to 2836 grams (6.25 lbs.) of copper sulfate in 5 gallons of solution at 70°C, stirred vigorously for 30 minutes (including the time of precipitation) at 70°C, filtered immediately and washed practically free from sodium sulfate and dried at a relatively low temperature (35-50°C) to a soft, adhesive, greenish-blue powder of fine amorphous particles containing about 53 per cent of metallic copper.

The sodium carbonate mix is the most difficult of the three to control but the color and reaction are fairly safe guides. The batch yields about 3 pounds of material.

Composition of Laboratory Samples

The analyses of two samples of basic copper sulfate prepared in the Station laboratory with an excess of calcium carbonate have been published (6, p. 747) but are again reported with a new hypothetical combination based on the theory of tribasic sulfate with the excess as copper hydroxide, which may or may not be more accurate. The theoretical composition, however, was merely incidental to the project and not pursued at length.

Basic Copper Sulfate

	Sample No. 1 *Per cent*	Sample No. 2 *Per cent*
Water, 100°C	7.880	8.900
Cupric oxide, CuO	32.732	32.356
Copper, Cu	(26.150)	(25.850)
Calcium oxide, CaO	17.750	17.770
Carbon dioxide, CO_2	0.803	0.805
Sulfur trioxide, SO_3	30.930	30.790

Hypothetical Combination

Tribasic sulfate, $4CuO.SO_3.4H_2O$	41.39	40.43
Copper hydroxide, $Cu(OH)_2$	6.39	6.76
Calcium sulfate, $CaSO_4.2H_2O$	51.36	51.41
Calcium carbonate, $CaCO_3$	1.83	1.83

As some of the hydrated compounds present were apparently unstable, the hygroscopic moisture determined is of little value and this may also account for the overrun in the calculations.

Another sample prepared with an excess of basic magnesium carbonate had the following composition:

Basic Copper Sulfate

	Per cent
Water, 103°C	0.694
Cupric oxide, CuO	67.316
Copper, Cu	(53.780)
Ferric oxide, Fe_2O_3	0.025
Magnesium oxide, MgO	0.400
Carbon dioxide, CO_2	0.939
Sulfur trioxide, SO_3	16.180

Hypothetical Combination

Tribasic sulfate, $4CuO.SO_3.4H_2O$	95.06
Copper hydroxide, $Cu(OH)_2$	1.06
Copper carbonate, $CuCO_3.Cu(OH)_2$	2.97
Ferric hydroxide, $Fe(OH)_3$	0.04
Basic magnesium carbonate, $4MgCo_3.Mg(OH)_2.5H_2O$	0.96

The product obtained with magnesium carbonate is more highly concentrated, as the magnesium sulfate is removed by washing, and tends to confirm the hypothesis as to formation of a tribasic salt.

Basic copper sulfate prepared with different carbonates varies somewhat in color, from batch to batch, but as a rule a greenish-blue to a light blue precipitate is preferable to a deeper colored product. After sieving, a good quality basic sulfate made from calcium carbonate should have a volume of 5 to 6 cubic centimeters to the gram; from magnesium carbonate, of about 3 c.c.; and from sodium carbonate, of about 2 c.c.

Character of the Commercial Product

From a chemical standpoint basic copper sulfate may be considered the active principle which together with gypsum and excess lime compose Bordeaux. The low basic sulfate prepared with calcium carbonate contains about 51+ per cent of gypsum while the high basic sulfate prepared with basic magnesium carbonate or sodium carbonate appears to be largely tribasic sulfate. Physically basic sulfate is not as highly dispersed as Bordeaux and therefore has a lower power of suspension, distribution (coverage), adhesiveness and general effectiveness. From the inception of the project the main objective was to prepare a Bordeaux substitute that could be readily dispersed in water and was substantially as effective in controlling diseases on vegetables and fruits as Bordeaux, but not necessarily of the same copper content. The use of basic sulfate as a dust has been of more recent application.

Since the Station laboratory is not equipped for quantity production, arrangements have been made, from time to time, with different chemical manufacturers to prepare basic copper sulfate for use in field work according to directions furnished. The G. Chem. Co. prepared low basic sulfate with calcium carbonate in 1925, two lots in 1926, and preliminary samples of high basic sulfate with basic magnesium carbonate in 1927. The M. Chem. Co. prepared high basic sulfate from sodium carbonate in 1927, and the C. Chem. Co. low and high basic sulfates with calcium carbonate and sodium carbonate, respectively, in 1928. Several manufacturers refused the work from lack of time, equipment or willingness to undertake a new product. With adequate tank agitators, rapid filtering apparatus, and other necessary equipment there does not seem to be any particular difficulty in producing basic sulfate, but without such facilities secondary reactions are likely to take place and more or less carbonate results. Furthermore, lack of adequate facilities generally injures the physical properties even more than the chemical, which is particularly objectionable in the case of copper fungicides where the size and character of the particles may be greater limiting factors in disease control than differences in composition. Basic sulfate, however, is generally acknowledged as being more efficient than basic carbonate of the same degree of dispersion. The absence of an appreciable amount of excess precipitant is to be noted in both high and low basic sulfates, and of by-products in high basic sulfate. The physical attributes sought are a soft, light, bulky, free-flowing product of fine amorphous particles having a high power of suspension in water, highly sustained air-floating properties as a dust, and good adherence to foliage and fruit. These characteristics are seldom attained in entirety but are more fully reproduced in the laboratory than in the factory in mass production. None of the firms appeared to have all the equipment needed to perform the work according to directions. The quality as a whole was rather inferior as judged by laboratory standards. In large measure the degree of dispersion is becoming recognized as the criterion and in practice is generally determined by suspension. The seven lots are summarized in Table 1.

The copper content of the several samples of low basic sulfate was fairly concordant and likewise those of the high basic sulfate. The amount of carbon dioxide indicates the presence of comparatively little carbonate except in three instances. As a whole the green-blue or light-blue lots seemed to be preferable to the darker colored. Most samples were soft, bulky and free from grit and of either a fibrous or powdery character. The fibrous samples were quite bulky and contained well developed spicules of calcium sulfate which were produced simultaneously with the basic sulfate and attached thereto, forming relatively large particles which agglomerated readily but did not pack. When the conditions

Table 1. Factory Prepared Basic Copper Sulfate

Lab. No.	Manufacturer	Basic copper sulfate	Copper content	Carbon dioxide	Color	Volume per gram	Flow	Size of particles	Remarks
			Per cent	*Qualitative*		*c. c.*		*Microns*	
1	G—	low	26.38	slight	blue	5.14	powdery	5.4	more amorphous than crystalline
2	G—	low	26.50	trace	light blue	7.60	powdery, slightly fibrous	7.2	crystalline
3	G—	low	26.31	slight	light blue	6.47	powdery	5.3	amorphous or too slightly crystalline to detect
4	G—	high	53.31	trace	green-blue	2.95	powdery	2.1	amorphous, slightly gritty
5	M—	high	52.95	trace	green-blue	2.14	powdery	3.6	amorphous
6	C—	low	26.45	much	dirty green	2.19	powdery, flourlike	5.6	amorphous or too slightly crystalline to detect
7	C—	high	52.56	much	dirty green	1.54	powdery, flourlike	2.9	amorphous
	Samples in composite				*Laboratory samples for comparison*				
a	30	low	26.15	sl. trace	blue	12.32	fibrous, agglomerates	7.1	crystalline
b	26	low	25.85	sl. trace	blue	10.12	fibrous, agglomerates	8.2	crystalline
c	4	low	25.85	trace	deep blue	8.92	powdery	5.9	crystalline
d	11	low	....	none	light blue	6.25	powdery, slightly fibrous, agglomerates	2.3	amorphous, gypsum spicules present
e	15	low	....	trace	green-blue	5.63	powdery	3.4	amorphous
f	22	high	53.78	trace	blue	3.25	powdery	5.5	amorphous
g	6	high	....	much	green-blue	1.87	powdery, sticky	1.8	amorphous
h	4	high	....	none	deep blue	4.42	powdery	2.0	amorphous
i	1	high	53.55	slight	green-blue	1.72	powdery	2.3	amorphous
j	2	high	....	......	blue	....	powdery	1.8	amorphous

Nos. 1, 2, 3, 6, a, b, c, d and e were prepared with calcium carbonate.
Nos. 4 and f were prepared with magnesium carbonate.
Nos. 5, 7, g, h, i and j were prepared with sodium carbonate.

of precipitation did not permit the growth of crystals, the product was powdery and the particles amorphous or too slightly crystalline to be detected. All the samples of high basic sulfate were amorphous. Nearly all the samples except the flourlike showed a fair flow in the bottle but poor on a pane of glass, and the fibrous were inferior to the powdery. The adhesive power of the fibrous samples to glass was also inferior to the powdery, and sample "g" with particles of 1.8 microns in size the most promising.

Field Work in 1925 with Commercial Basic Copper Sulfate

Attention has been called (6, p. 748) to the relative effectiveness of laboratory prepared basic copper sulfate and of Bordeaux with various spores as determined by W. L. Doran of the department of botany of this Station, using the method of Reddick and Wallace (13). Slightly greater concentration (copper content) of basic sulfate than of Bordeaux was required to inhibit the germination of the more resistant fungi. In addition (6, p. 749–750) field experiments were conducted in 1925 by E. F. Guba of the Market Garden Field Station at Waltham, Mass., to determine the relative effectiveness of basic copper sulfate (lot 1) and of Bordeaux 4–4–50 in controlling anthracnose and downy mildew on cucumbers and early and late blights on celery. Observations and yields indicate that basic sulfate was substantially as effective, per unit of copper, as Bordeaux in both instances.

Field Work in 1926

The field work of 1926 with basic sulfate includes experiments with cucumbers and celery at the Market Garden Field Station at Waltham, with potatoes on the farm of E. S. Fulton at North Amherst, and with apples, plums and grapes in the College orchard and vineyard. The experiments with cucumbers and celery were conducted by E. F. Guba as in the previous year.

Cucumbers

The cucumber experiment consisted of 3 plots, 132 by 12 feet, of 2 rows each, planted in hills 6 feet apart each way. The seed was sown three times and that of June 16 finally gave a successful stand. The plants were sprayed before vining by a knapsack sprayer and later by a Bean Truck or Arlington X. L. sprayer with Friend nozzles under 200 to 250 pounds pressure. Frequent applications were necessary on account of rains. Lead arsenate and lime 2–2–50 were applied on July 7, 15, 20 and 26 for the striped beetle. Vining began about August 2. Basic sulfate (lot 2) 3.84–50 and Bordeaux 4–4–50 with lead arsenate 2–50 were applied on August 2, 5 and 11; the fungicides alone on August 17 and 25, and the fungicides with one-half pint of nicotine sulfate for green aphis on September 1. The basic sulfate was mixed with approximately 6.17 ounces of Wilkinite and 0.88 ounces of crude saponin to increase wetting, spreading and adhesiveness. The cucumbers were inoculated with anthracnose fungus, *Colletotrichum lagenarium* (Pass.) Ells. and Hals., on August 17 and 27. The fungicides were prominent on the foliage at the time. Powdery mildew, *Erysiphe cichoracearum* D. C., appeared naturally and developed on the check plot.

The season was unfavorable for cucurbits, due to poor growing conditions and a fairly general infestation of mosaic, bacterial wilt, striped beetles and green aphis which affected both the stand and the yield. Leaf counts made on September 8 and 10 may serve, however, to indicate the relative effectiveness of the two fungicides.

Table 2. Relative Effectiveness of Basic Copper Sulfate and Bordeaux in Controlling Anthracnose of Cucumbers

Fungicide	Copper content	Number of appli- cations	Total leaves	Healthy leaves	Diseased leaves	
	Per cent		*No.*	*No.*	*No.*	*Per cent*
Basic copper sulfate 3.84-50..	*0.25*	10	**1251**	1215	36	*2.88*
Bordeaux mixture 4-4-50....	*0.25*	10	**1544**	1498	46	*2.98*
Check....................	*0.00*	0	**1857**	1221	636	*34.25*

In conclusion Guba states that basic copper sulfate showed no inferiority to homemade Bordeaux in the control of anthracnose on cucumbers. Both readily controlled powdery mildew which was apparent on practically all leaves in the check. Both fungicides appeared to be equally toxic to young cucumber leaves although the injury could not be considered serious.

Celery

The celery experiment consisted of 4 plots, 64 by 12 feet, of 4 rows, 3 feet apart, each. The plants were raised in a seed bed and set out on July 15. Basic copper sulfate (lot 2) 3.84–50 and Bordeaux 4–4–50 were applied on June 25 to the plants in the seed bed when 1.5 inches high, and again on July 9; in the field on August 2, 5, 11, 17 and 25 and September 1, 9 and 21. Nicotine sulfate was added on September 9. The basic sulfate was applied both with and without the combined spreader.

A knapsack sprayer was used in the seed bed and in the field a Bean Truck or Arlington X. L. sprayer with Friend nozzles under 200 to 250 pounds pressure covering 4 rows, 3 nozzles to a row. The entire planting was inoculated with a spore suspension of *Cercospora apii* Fries and *Septoria apii* (Br. and Cav.) Rost. on the nights of September 9 and 21, following treatments. The celery was boarded on October 7 and harvested on October 19 and 25, at which time leaf counts were made of the two interior rows of each plot.

Table 3. Relative Effectiveness of Basic Copper Sulfate and Bordeaux in Controlling Early and Late Blights of Celery

Fungicide	Copper content	Number of appli- cations	Total leaves	Healthy leaves	Diseased leaves	
	Per cent		*No.*	*No.*	*No.*	*Per cent*
Basic copper sulfate 3.84-50..	*0.25*	10				
Leaf count Oct. 19........................			**5468**	5400	68	*1.24*
Oct. 25........................			**2310**	2258	52	*2.25*
Mean..						**1.54**
Basic copper sulfate 3.84-50, with spreader and adhesive	*0.25*	10				
Leaf count Oct. 19........................			**4232**	4171	61	*1.44*
Oct. 25........................			**2272**	2200	72	*3.17*
Mean..						**2.04**
Bordeaux mixture 4-4-50....	*0.25*	10				
Leaf count Oct. 19........................			**4054**	3960	94	*2.32*
Oct. 25........................			**3035**	2965	70	*2.31*
Mean..						**2.31**
Check....................	*0.00*	0				
Leaf count Oct. 19........................			**4930**	2793	2137	*43.35*
Oct. 25........................			**2366**	1467	899	*38.00*
Mean..						**41.61**

From the leaf counts made on October 25, early blight was rather more prominent on the sprayed plots and late blight on the check. The celery from the treated plots was excellent with a negligible percentage of infection. That from the check plots showed considerable early and late blights, confined largely to the outer leaves, which did not materially affect its value. The basic sulfate without spreader was fully as effective as with the combined spreader or as Bordeaux. Saponin increased wetting and spreading, but Wilkinite proved of no particular value unless possibly to increase visibility (Guba).

Potatoes

Experiments were conducted on the farm of E. S. Fulton at North Amherst under the supervision of W. L. Doran of the department of botany of this Station to determine the relative effectiveness of basic copper sulfate and of Bordeaux in controlling early and late blights on potatoes. Uncertified Green Mountain seed was used without disinfecting. The fungicides were basic copper sulfate (lot 3) 4–50 with combined spreader and homemade Bordeaux 4–4–50, to which was added lead arsenate when necessary for the control of the Colorado potato beetle. Applications were made on July 15 and 26 and August 9 and 18 with a Yellow Jacket equipment under a pressure of 175 pounds, 2 nozzles to a row, and about 90 gallons to the acre. Leaf hopper or tipburn injury, leaf-roll and late blight were the principal infestations of the season. Leaf hoppers were very prevalent and no nicotine sulfate was employed. Early blight was inappreciable; late blight was late in appearing and probably did not constitute a serious factor. On harvesting there was not over 1 or 2 per cent of tuber rot. The yield was calculated from the weight of the two inside rows (equivalent to ⅛ acre) in each plot on the basis of marketable potatoes, 60 pounds to the bushel.

Table 4. Relative Effectiveness of Basic Copper Sulfate and Bordeaux in Controlling Early and Late Blights of Potatoes—As Shown by Yields

Fungicide	Copper content	Number of applications	Number of rows treated	Yield per acre	Gain or loss over check	
	Per cent			*Bu.*	*Bu.*	*Per cent*
Basic copper sulfate 4-50						
East plot	*0.25*	4	8	190.4	—6.4	*—3.25*
West plot	*0.25*	4	8	189.6	—7.2	*—3.66*
Average				**190.0**	**—6.8**	**—3.46**
Bordeaux mixture 4-4-50						
East plot	*0.26*	4	8	192.0	—4.8	*—2.44*
West plot	*0.26*	4	8	217.6	+20.8	*+10.57*
Average				**204.8**	**+8.0**	**+4.07**
Check	*0.00*	0	4	**196.8**	....	....

Observations and yields indicate that basic sulfate was rather less efficient in controlling late blight than Bordeaux, although only one of the sprayed plots showed an increase in yield over the check. Furthermore, the number of applications would have been decidedly inadequate in so rainy a season had blights appeared earlier.

Fruits.

Experiments were conducted in the College orchard and vineyard under the supervision of J. K. Shaw and O. C. Roberts to determine disease control and foliage injury of basic sulfate on Baldwin and McIntosh apples, Monarch plums and Moore's early grapes. The highest concentration employed was 4 pounds to 50 gallons with combined spreader. Concentrations of 3 and 2 pounds were obtained by increasing the dilution of the previous mixture. For apples a large-sized Friend spray apparatus, under 300 pounds pressure, with two Boyce guns, parallel nozzles and 5/64-inch discs was used. Prepink (May 7), pink (May 13), and calyx (June 2) applications were made of about 6 gallons to a tree. Basic sulfate failed to control scab as effectively as liquid lime-sulfur, injured the foliage and russeted the fruit. The latter was not particularly serious with the lowest concentration.

For plums and grapes a 50-gallon hand outfit, under approximately 175 pounds pressure, equipped with rod and disc nozzle, was employed. The plums were sprayed on May 24 and June 8 and the grapes on May 19, June 8 and July 17. Roberts reported that the spreading and adhesiveness of basic sulfate appeared to be satisfactory. The effectiveness could not be determined as there was practically no disease present. Foliage injury was observed on all the plants sprayed, increasing with concentration, but evidently was not appreciable on the fruit of plums and grapes.

Miscellaneous

Dr. W. P. Brooks of Amherst sprayed currants, English gooseberry, nine varieties of grapes, tea roses and phlox with basic sulfate 4-50 with combined spreader and did not observe any foliage injury.

L. F. Kinney of Kingston, Rhode Island, sprayed seedlings of *Rhododendron Catawbiense* in flats with basic sulfate 2.5-50 without injury.

Field Work in 1927

The field work of 1927 with basic copper sulfate includes experiments with cucumbers and celery at the Market Garden Field Station at Waltham, with potatoes on the Experiment Station plots at Amherst and on the farm of G. Fred Pelissier at Hadley, and with apples and grapes in the College orchard and vineyard. The basic sulfate was applied both as a spray and mixed with a free-flowing talc as a dust. The experiments with cucumbers and celery were conducted by E. F. Guba as in previous years.

Cucumbers

The objective was to determine the relative efficiency of spray and dust applications of basic sulfate in controlling anthracnose and mildews on cucumbers. The experiment consisted of 3 plots, 120 by 12 feet, of 2 rows each, planted in hills 6 feet apart each way. Several preliminary treatments were found necessary to control insects. Bordeaux 4-4-50 was applied for flea beetles after the first leaves appeared (June 8); sodium fluosilicate dust for striped beetles on June 17, 21 and 30 and July 8; and lead arsenate, lime and nicotine sulfate 1.50-2-0.5 pt.-50 for striped beetles on July 14. The regular spray consisted of basic sulfate (lot 5), lead arsenate and raw linseed oil 2-1.5-0.5 pt.-50 and contained about 0.26 per cent copper and 0.07 per cent arsenic. The dust consisted of basic sulfate (lot 5), lead arsenate and talc and contained about 7.02 per cent copper and 4.01 per cent arsenic. The plants were treated on July 21 when vining began and on July 28 and August 4. A 3-gallon knapsack sprayer and a 2-quart Feeney duster were employed for application. The spray left a thin, hardly perceptible residue which disappeared entirely after the least rainfall. The oil was not found satisfactory as a spreader or adhesive. Dusting resulted in a heavy deposit on the foliage and protection of the lower surface of the leaves. Neither application caused perceptible injury. The vines made a poor growth due to severe stunting and foliage injury resulting from applications of sodium fluosilicate from which they did not recover and also from inability to control the striped beetles and accompanying mosaic. The cucumbers were inoculated with a spore suspension of anthracnose, *Colletotrichum lagenarium* (Pass.) Ells. and Hals., on July 21, and leaf counts made on August 11.

Table 5. Effectiveness of Basic Copper Sulfate in Controlling Anthracnose of Cucumbers

Form of application	Copper content	Number of applications	Total leaves	Healthy leaves	Diseased leaves	
	Per cent		*No.*	*No.*	*No.*	*Per cent*
Spray	*0.26*	3	**374**	29	345	*92.25*
Dust	*7.02*	3	**461**	88	373	*80.91*
Check	*0.00*	0	**340**	30	310	*91.18*

Dr. Guba reported that it was impossible to maintain protection this season due to continuous heavy rains. The dust, however, appears to have afforded slight protection.

Celery

Three plots, 120 by 12 feet, of 4 rows, 3 feet apart, each, were employed. The spray consisted of basic sulfate (lot 5) and raw linseed oil 2–0.5 pt.–50 and contained about 0.26 per cent copper. The oil proved unsatisfactory but was omitted only on August 26. The dust consisted of basic sulfate (lot 5) and talc and contained about 7.02 per cent copper. Treatments were made on August 10, 17 and 26 and September 2, 12 and 20. The celery was inoculated with a spore suspension of early and late blights on August 26, boarded on September 26, harvested on October 14 to 16 and the yield of marketable celery determined.

Table 6. Effect of Basic Copper Sulfate on the Yield and Grade of Celery

Form of application	Copper content	Number of applications	Number of Bunches			Increase over check Total bunches
			Grade 1	Grade 2	Total	
	Per cent					*Per cent*
Spray	*0.26*	6	163	45	**208**	*38.67*
Dust	*7.02*	6	192	26	**218**	*45.33*
Check	*0.00*	0	93	57	**150**	....

Grade 1: 3 good sized stalks to the bunch, 18 bunches to the box.
Grade 2: 4-7 small stalks to the bunch, 18 bunches to the box.

The yield and the grade were increased by the use of basic sulfate, particularly the dust.

Potatoes

Dusting experiments were conducted on the Station rotation 0.05 acre plots Nos. 7, 17, 53, 54 and 55 and 0.03 acre intervening strips under the supervision of J. P. Jones to determine the effectiveness of basic copper sulfate in controlling early and late blight on potatoes. The seed was Massachusetts certified Green Mountain, grown in Charlemont and disinfected with corrosive sublimate. The seed was planted on May 7, and the crop harvested on September 16. The cultural and fertilizer treatment was of the usual character. The plots were dusted on June 16 and 25, July 1, 8, 19 and 29 and August 6 with a mixture of basic sulfate (lot 5), lead arsenate and talc containing about 7.52 per cent copper and

4.00 per cent arsenic. The mixture applied on July 29 did not contain arsenic. The amount of dust required increased with the growth of the plants but averaged about 48.10 pounds an acre for each treatment. The persistence of the Colorado potato beetle necessitated the continued use of arsenic. Two per cent nicotine dust was applied on July 27 and August 3 at the rate of about 20 pounds an acre but did not prove particularly effective. Weather conditions and ladybugs, however, prevented the rapid spread of aphis and leaf hoppers were not abundant (A. I. Bourne). Foliage injury was inappreciable as a whole although occasionally burning was observed where a large amount of dust accidently lodged on the plant (J. P. Jones). For applying the dusts two hand dusters, the American Beauty and the double action Cheeseman, were tested and gave "fair" distribution, but the former was considered easier to operate and was employed.

Growth was excellent until July 19, when yellowing of the lower leaves was observed, apparently due to age or to excessive shading by the dense growth of vines, as there was no evidence of disease and leaf hoppers and aphis were not particularly destructive. By August 6 most of the leaves were severely injured by tip burn and on August 20 nearly all were dead (Jones). The amount of early blight was negligible but some late blight appeared about the first of September after most of the foliage was dead and caused 1 to 2 per cent of tuber rot (Doran). The yield of the several plots is reported on the basis of 60 pounds to the bushel.

Table 7. Yield of Potatoes on the Rotation Plots. (Per Acre.)

Location of plots	Total Yield	Grade 1	Grade 2	Grade 3	Rotted	Rotted
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Lbs.*	*Per cent*
On high ground...........	**241.8**	121.3	79.8	40.3	22.5	*0.16*
On slope....................	**199.2**	99.4	60.0	36.2	213.3	*1.81*

Grade 1: All disease free potatoes above 1.75 inches in diameter.
Grade 2: All disease free potatoes above 1 inch in diameter, not included in Grade 1.
Grade 3: All disease free potatoes 1 inch or under in diameter.

The low yield has been ascribed to leaf hoppers and aphis (Jones) and to the effect of previous crops (Snell). The fact that the yield was appreciably larger and the amount of rot less on the plots which were better located as to elevation and natural drainage (Snell) would seem to indicate that the abnormal precipitation during August was a limiting factor. As there were no check plots the effectiveness of the dust must be judged largely from observations of the foliage and the amount of tuber rot.

A spraying experiment was conducted on the farm of G. Fred Pelissier at Hadley (8 acres) to determine the relative effectiveness of basic copper sulfate and Bordeaux in controlling early and late blights on potatoes. The seed was certified Rural Russets, raised by K. C. Livermore of Honeoye Falls, New York, and disinfected with corrosive sublimate. Planting was begun on May 4. The entire field received similar cultural and fertilizer treatment and was sprayed seven times from June 27 to September 9 at the rate of 100 gallons an acre. To the major portion of the field was applied a mixture of Bordeaux 4–4–50 and lead arsenate 2–50 containing about 0.24 per cent copper and 0.09 per cent arsenic. Chemical hydrated lime or finishing lime (Tiger Brand) was used in place of quicklime, pound for pound, in preparing the Bordeaux. To an inner strip of one acre was applied a mixture of basic sulfate (lot 5), lead arsenate and raw linseed oil 2–2–0.5 pt.–50 containing about 0.25 per cent copper and 0.09 per cent arsenic.

A traction field force pump of 100 gallons capacity with a boom covering 4 rows, 3 nozzles to a row, was employed. Repeated use of lead arsenate was found necessary to check the Colorado potato beetle. Leaf hoppers were not prominent and aphis constituted a minor factor; nevertheless, two treatments of nicotine sulfate were applied to one acre but the results did not warrant the added expense (Pelissier). W. L. Doran observed some late blight but "not over 1 or 2 per cent of late blight rot in the entire field regardless of the fungicide used." A considerable number of vines were still green when the crop was harvested on October 10. The yield calculated from a single determination of 5 rods, of 2 rows each, was 301.8 bushels an acre for basic sulfate and 451.7 bushels for Bordeaux. Neither the life of the vines nor the amount of disease could account for any such differences.

Apples

A spraying experiment was conducted on Block E of the Station orchard under the supervision of J. K. Shaw and W. L. Cutler to determine the relative effectiveness of basic sulfate and lime-sulfur in controlling scab on McIntosh and Baldwin apples and the amount of injury. A mixture of high and low basic sulfates (lots 4 and 2) was employed in two concentrations, dilute and triple-strength. Whenever the low basic sulfate was used, in whole or in part, the amount was doubled. The dilute mixture consisted of basic sulfate, lead arsenate and saponin 0.50–1.50–0.055[1]–50 and contained about 0.06 per cent copper and 0.07 per cent arsenic. In the third and fourth applications raw linseed oil 0.50 pt.–50 was substituted for saponin. The triple-strength mixture was the same as the dilute except as to copper content and contained about 0.19 per cent copper. A standard mixture of liquid lime-sulfur, lead arsenate and calcium caseinate 1.25 gals.–1.5–0.5–50 was applied to similar trees for comparative purposes. A Friend power sprayer with 250-gallon tank under 275 pounds pressure and Friend guns with $\frac{3}{32}$ disc nozzles were employed for the several mixtures. Care was taken to cover the trees thoroughly but to avoid drenching.

In the pre-pink spray (April 21) the dilute basic sulfate mixture with saponin injured the fruit buds a little, about the same as lime-sulfur, but the concentrated damaged the buds seriously. In the pink spray (April 25) the dilute mixture with saponin injured the buds slightly more than lime-sulfur, but the concentrated killed the buds and injured the young leaves. In the calyx spray (May 19) the dilute mixture with linseed oil caused less injury than lime-sulfur. The use of the concentrated was discontinued. A later application (July 1) of the dilute mixture with linseed oil substantiated previous results. The oil dispersed readily in the mixture and increased adhesiveness. McIntosh foliage is particularly sensitive to copper injury. Trees with 85 per cent bloom, set 71 per cent with dilute basic sulfate and 88 per cent with lime-sulfur. Very little or no scab was observed with basic sulfate or lime-sulfur.

A dusting experiment was conducted in the College orchard under the supervision of Brooks D. Drain to determine the effectiveness of basic copper sulfate in disease control on McIntosh apples and Bartlett pears and the amount of injury. High and low basic sulfates (lots 5 and 2) were employed in two concentrations, dilute and double-strength. The dilute mixture consisted of basic sulfate, lead arsenate, and talc and contained about 2.50 per cent copper and 2 per cent arsenic. The double-strength contained about 5.00 per cent copper but was otherwise the same. Crude saponin, 1 pound in 100, was incorporated in both mixtures applied on May 7 and June 2 to apples and on June 2 to pears but was excluded from the mixtures applied on August 5 to apples and pears.

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[1] 25 grams.

Drain reported that with both dusts there was a small amount of russet on McIntosh apples but no foliage injury. A few scab spots were detected on trees receiving the dilute mixture. Bartlett pears showed neither scab nor injury. In addition Drain stated that the dust distributed well, and appeared to have good adhesiveness.

Grapes

Experiments were conducted in the College vineyard, under the supervision of O. C. Roberts, to determine the relative effectiveness of spray and dust applications of basic copper sulfate (lots 5 and 2) and of Bordeaux 4–4–50 in disease control and foliage injury on grapes. Two concentrations of sprays and two of dusts with lead arsenate in all cases were employed as with apples. Crude saponin 25 gms.–50 was used in the first three spray applications and raw linseed oil 1 pt.–50 in the fourth. Crude saponin 1 pound in 100 was incorporated in the first three dust applications and omitted in the fourth. The variety Worden was used in the tests. The vines, located in a portion of the vineyard where conditions were relatively uniform, were divided into 6 groups (plots), of 3 rows each, with approximately 9 vines to a row. Five plots received dilute and concentrated sprays, dilute and concentrated dusts, and Bordeaux, respectively. The sixth served as a check. The details of the treatments were as follows:

Fungicide	Copper Content	Number of Applications	Amount of Material
	Per cent		
Dilute spray	0.06	4	35.5 Gals.
Concentrated spray	0.19	4	37.0 Gals.
Dilute dust	2.50	4	8.0 Lbs.
Concentrated dust	5.00	4	7.5 Lbs.
Bordeaux	0.24	4	35.5 Gals.
Check	0.00	0	0.0

Spray and dust treatments of basic sulfate were applied when the first leaves were about to appear (May 14), when the shoots were about 12 inches long (June 11), when the grapes were about the size of peas (July 18), and when the grapes were from ½ to ⅔ grown (August 11). The weather conditions at the time of application were as follows:

May 14—clear, no wind, 53° Fahr.
June 11—partly cloudy, light breeze, 70° Fahr.
July 18—clear, light southerly breeze, high humidity, 65° Fahr.
August 11—partly cloudy, no wind, 65° Fahr.

The Bordeaux was applied on May 14, June 10, July 12 and August 11. The sprays were applied under 75 to 100 pounds pressure with a double action, Deming barrel hand pump equipped with two lines of hose to which were attached rods and disc nozzles. The dusts were applied with an American Beauty hand duster. The adhesiveness of the spray was considered poor, partly due, it is believed, to the similarity in color of the spray residue and foliage, while that of the dusts was highly commended.

The concentrated spray and dust caused considerable injury to the foliage, the dilute spray a little and the dilute dust practically none. The leaves remained green 10 to 14 days longer than with Bordeaux and complete defoliation was delayed fully as many days. The Bordeaux was the most injurious of all treatments and the "burned" condition of the foliage was decidedly apparent. This may have been due to carbonating of the lime. The rainfall during the summer was comparatively high and the temperature low. Some mildew was detected on the check rows during the latter part of August and the first of September, but no black-rot was observed on any vines. There was not sufficient disease present at any time to constitute a real test of the fungicides. The fruit was of good quality from all vines including the checks, and there seemed to be no appreciable injury from the various treatments. The yields are not reported on account of pilfering of the fruit.

Field Work in 1928

The field work of 1928 with basic sulfate includes experiments with celery on the vegetable garden plots at the College, with potatoes on the Experiment Station plots and on the College farm, and with apples and grapes in the College orchard and vineyard. Low and high basic sulfates were employed in both spray and dust applications.

Celery

Spraying and dusting experiments were conducted on the College grounds, under the supervision of G. C. Stout, to determine the relative effectiveness of low and high basic sulfates (lots 6 and 7), Bordeaux 4–4–50 and a commercial monohydrated copper sulfate-hydrated lime dust (copper-lime dust) in controlling early and late blights on celery. The basic sulfates with raw linseed oil 1.25 pts.–50 as a spreader and sticker were applied as sprays at a concentration of 0.24 per cent copper, the same as Bordeaux 4–4–50. The basic sulfates mixed with a free-flowing talc were applied as dusts which contained 6.80 per cent copper, the same as the guarantee of the copper-lime dust. The sprays were applied with a barrel pump under about 75 pounds pressure and the dusts with a Niagara hand duster. The field was divided into plots of 4 rows each to which the several fungicides were applied, and 2½ rows for checks. The celery plants (Giant Pascal) were set rather late and made a poor growth due to unfavorable weather conditions. The fungicides were applied on July 30, August 9, 21 and 31 and September 28. Doran observed late blight on August 18 but no difference between plots. On October 29 there was late blight on the older leaves of all plots. No copper injury was noted. From general appearance the sprays were the most effective, followed by the dusts and checks. Bourne observed a few plant lice equally distributed. The celery did not reach marketable size, but the two middle rows of each plot were pulled and weighed for yield records.

Table 8. Relative Effectiveness of Low and High Basic Sulfates, Bordeaux and Copper-lime Dust in Controlling Early and Late Blights of Celery,—As Shown by Yields

Fungicide	Copper content	Number of applications	Yield	Increase over check
	Per cent		*Lbs.*	*Per cent*
Low basic sulfate spray.......	*0.24*	5	206	*145.24*
High basic sulfate spray.........	*0.24*	5	228	*171.43*
Bordeaux 4-4-50................	*0.24*	5	273	*105.95*
Check (one row only)...........	*0.00*	0	42	.....
Low basic sulfate dust..........	*6.80*	5	94	*20.51*
High basic sulfate dust..........	*6.80*	5	102	*30.77*
Commercial copper-lime dust.....	*6.80*	5	138	*76.92*
Check (one row only)...........	*0.00*	0	39	.....

There were no replications and the plots suffered unequally from adverse weather conditions so that the experiment has little significance except to indicate that 0.24 per cent sprays were more effective than 6.80 per cent dusts.

Potatoes

A spraying experiment was conducted on a 3.55 acre strip on the Farm field north 1, under the supervision of M. H. Cubbon, to determine the relative effectiveness of low and high basic sulfates (lots 6 and 7) and Bordeaux 4–4–50 in controlling early and late blights on potatoes. The field was undulating from east to west and suffered from excessive water in the dips. It was divided into 2 sections (156 by 495 feet), east and west, of 13 four-row plots each. The east half was evidently more uniform than the west. The entire field was manured at the rate of 15 tons to the acre, and in addition the east half received 1100 pounds an acre of a high commercial fertilizer and the west half 600 pounds of the same mixture. The seed was certified Green Mountain disinfected with corrosive sublimate. The potatoes were planted on May 14 and 15 at the rate of 25 bushels an acre on the two southern rows of each plot 1 to 9 inclusive and 15 bushels an acre on the northern rows of plots 1 to 9 and all rows of plots 10 to 13 inclusive. The crop was harvested between September 17 and October 10. The basic sulfates with linseed oil 0.50 pt.–50 were applied at a concentration of 0.24 per cent copper, the same as Bordeaux 4–4–50 and with lead arsenate 2–50 when necessary. Chemical hydrated lime was used in preparing the Bordeaux. A "Gray Jacket" traction field force pump with a 100-gallon tank, under 200 to 300 pounds pressure, and a boom covering 4 rows, 3 nozzles to a row, was employed. The amount of spray varied somewhat with the pressure from 100 to 135 gallons an acre. The plants were slow in starting but made a fair growth considering the season. The vines were sprayed practically every week as long as the tops continued green, 10 treatments. Doran observed some early blight and tipburn on August 10 and late blight on August 17. Insects were not a limiting factor (Bourne). The yield records were determined from the 2 middle rows of every plot.

On 25 out of 28 plots the fungicides reduced the amount of rot. The Bordeaux was the most effective followed by high and low basic sulfates. The extreme variations in results due to inequalities in soil, natural drainage, excessive rainfall, etc., warrant only general deductions as to trend. The Bordeaux was unquestionably superior to the basic sulfates probably due to its greater dispersion.

Dusting experiments were conducted on the Station rotation 0.08 acre plots Nos. 51, 54 and 57 and on the west half of Field B 0.205 acre plot, under the supervision of J. P. Jones, to determine the relative effectiveness of low and high basic sulfates and a commercial monohydrated copper sulfate-hydrated lime dust in controlling early and late blights on potatoes. On plot 51 potatoes alternate every other year with onions and on plot 57 with tobacco, while on plot 54 potatoes have been grown continuously for five years. These plots received the equivalent of 2500 pounds of 5–8–7 fertilizer an acre. The northern portion of the west half of Field B was in potatoes in 1927 and the southern portion in mangels. Field B received approximately the equivalent of 2000 pounds of 5–8–7 fertilizer an acre. The seed was certified Green Mountain disinfected with corrosive sublimate. The potatoes were planted on May 10 and harvested on September 14 when the vines were nearly dead. The growth during the entire season indicated adequate fertilizer treatment. The vines remained green longer than usual in spite of late blight, probably because tipburn injury was negligible (Jones). The basic sulfates (lots 6 and 7) were mixed with a free-flowing talc, with and without lead arsenate, and contained 5.41 per cent copper and 4.00 per cent arsenic in the first instance and 6.80 per cent copper in the latter. The commercial copper-lime dust was guaranteed to contain 6.80 per cent copper[1] and when mixed with lead arsenate was calculated to contain 5.41 per cent copper and 4.00 per cent arsenic.

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[1] Actually tested 7.70%.

Table 9. Relative Effectiveness of Low and High Basic Sulfate and Bordeaux Sprays in Controlling Early and Late Blights of Potatoes

Plot	Fungicide	Total Yield	Grade 1	Grade 2	Grade 3	Rotted	Rotted	Gain or loss over check	
								Grade 1	Rotted
		Bu.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Per cent*	*Per cent*	*Per cent*
East	*(Seed 25 Bu.)*								
2	Low basic sulfate	180.4	115.2	32.8	17.2	15.2	*8.48*	*44.18*	*55.69*
4	High basic sulfate	182.7	107.8	38.2	28.4	8.3	*4.54*	*34.92*	*75.80*
1	Bordeaux 4-4-50	203.4	142.2	26.0	22.5	12.7	*6.24*	*77.97*	*62.97*
3	Bordeaux 4-4-50	208.3	152.0	27.9	18.6	9.8	*4.70*	*90.24*	*71.43*
7	Bordeaux 4-4-50	164.2	123.0	23.5	15.2	2.5	*1.52*	*53.94*	*92.71*
9	Bordeaux 4-4-50	209.3	118.6	55.9	27.0	7.8	*3.73*	*48.44*	*77.26*
5	Check	159.8	79.9	29.9	15.7	34.3	*21.46*	.....	....
	(Seed 15 Bu.)								
2	Low basic sulfate	186.7	113.2	35.3	20.1	18.1	*9.69*	*124.16*	*29.02*
10	Low basic sulfate	166.8	110.0	34.8	17.6	4.4	*2.64*	*117.82*	*82.75*
4	High basic sulfate	179.4	111.3	32.8	24.0	11.3	*6.30*	*120.40*	*55.69*
11	High basic sulfate	157.4	99.5	33.6	17.2	7.1	*4.51*	*97.03*	*72.16*
1	Bordeaux 4-4-50	193.6	158.8	19.6	11.8	3.4	*1.76*	*214.46*	*86.67*
3	Bordeaux 4-4-50	220.6	145.6	30.4	22.1	22.5	*10.20*	*188.32*	*11.76*
7	Bordeaux 4-4-50	148.6	91.2	35.3	20.1	2.0	*1.35*	*80.59*	*92.16*
9	Bordeaux 4-4-50	201.9	128.9	44.1	19.6	9.3	*4.61*	*155.25*	*63.53*
5	Check	114.7	50.5	20.1	18.6	25.5	*22.23*	.....	....
West	*(Seed 25 Bu.)*								
2	Low basic sulfate	162.7	104.9	34.3	12.7	10.8	*6.64*	*—4.03*	*47.57*
4	High basic sulfate	197.5	141.7	37.7	14.2	3.9	*1.97*	*29.64*	*81.07*
1	Bordeaux 4-4-50	146.1	102.0	24.5	8.8	10.8	*7.39*	*—6.68*	*47.57*
3	Bordeaux 4-4-50	208.7	148.5	33.3	19.1	7.8	*3.74*	*35.86*	*62.14*
7	Bordeaux 4-4-50	266.7	202.0	36.8	19.1	8.8	*3.30*	*84.81*	*57.28*
9	Bordeaux 4-4-50	261.3	197.0	37.3	16.2	10.8	*4.13*	*80.24*	*47.57*
5	Check	208.3	109.3	42.6	35.8	20.6	*9.89*	.....	....
	(Seed 15 Bu.)								
2	Low basic sulfate	140.7	87.7	30.9	15.7	6.4	*4.55*	*—4.36*	*49.61*
10	Low basic sulfate	199.8	135.3	37.5	15.0	12.0	*6.01*	*47.55*	*5.51*
4	High basic sulfate	217.7	140.7	36.8	20.6	19.6	*9.00*	*53.44*	*—54.33*
11	High basic sulfate	180.1	117.4	33.8	15.9	13.0	*7.22*	*28.03*	*—2.36*
1	Bordeaux 4-4-50	244.1	160.8	34.3	45.6	3.4	*1.39*	*75.35*	*73.23*
3	Bordeaux 4-4-50	198.0	149.5	29.4	15.7	3.4	*1.72*	*63.03*	*73.23*
7	Bordeaux 4-4-50	243.1	184.8	31.9	18.1	8.3	*3.41*	*101.53*	*34.65*
9	Bordeaux 4-4-50	239.7	168.1	32.4	19.6	19.6	*8.18*	*83.32*	*—54.33*
5	Check	164.7	91.7	29.4	30.9	12.7	*7.71*	.....	....
	Average acre yield	192.4	127.8	33.2	20.0	11.4	5.95	.....	....

Average Percentage Gain or Loss Over Checks

	Grade 1	Rotted
Low basic sulfate	40.69	49.05
High basic sulfate	51.69	51.87
Bordeaux 4-4-50	79.01	61.63

Table 10. Relative Effectiveness of Low and High Basic Sulfate and Copper-lime Dusts in Controlling Early and Late Blights on Potatoes

Plot	Fungicide	Total Yield	Grade 1	Grade 2	Grade 3	Rotted	Rotted	Gain or loss over check	
								Grade 1	Rotted
		Bu.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Per cent*	*Per cent*	*Per cent*
51 D	Low basic sulfate	**261.0**	132.0	49.0	37.0	43.0	*16.48*	*50.00*	*57.43*
51 B	High basic sulfate	**266.0**	166.0	34.0	26.0	40.0	*15.04*	*88.64*	*60.40*
51 C	Copper-lime dust	**292.0**	188.0	36.0	31.0	37.0	*12.67*	*113.64*	*63.37*
51 A	Check	**225.0**	88.0	15.0	21.0	101.0	*44.89*	....	....
54 D	Low basic sulfate	**217.0**	134.0	41.0	37.0	5.0	*2.30*	*32.67*	*90.57*
54 B	High basic sulfate	**203.0**	123.0	30.0	26.0	24.0	*11.82*	*21.78*	*54.72*
54 C	Copper-lime dust	**251.0**	166.0	32.0	40.0	13.0	*5.18*	*64.36*	*75.47*
54 A	Check	**213.0**	101.0	31.0	28.0	53.0	*24.88*	....	....
57 D	Low basic sulfate	**235.0**	152.0	38.0	34.0	11.0	*4.68*	*43.40*	*77.55*
57 B	High basic sulfate	**241.0**	157.0	30.0	34.0	20.0	*8.30*	*48.11*	*59.18*
57 C	Copper-lime dust	**257.0**	186.0	30.0	29.0	12.0	*4.67*	*75.47*	*75.51*
57 A	Check	**219.0**	106.0	32.0	32.0	49.0	*22.37*	....	....
B 4	Low basic sulfate	**226.0**	167.0	30.5	26.0	2.5	*1.11*	*62.29*	*95.61*
B 8	Low basic sulfate	**232.5**	162.6	39.4	26.7	3.8	*1.63*	*58.02*	*93.33*
B 2	High basic sulfate	**273.7**	181.6	41.9	38.1	12.1	*4.42*	*76.48*	*78.75*
B 6	High basic sulfate	**248.9**	172.7	39.4	27.9	8.9	*3.58*	*67.83*	*84.37*
B 3	Copper-lime dust	**269.2**	182.9	48.9	33.0	4.4	*1.63*	*77.75*	*92.27*
B 7	Copper-lime dust	**213.4**	133.4	44.5	33.0	2.5	*1.17*	*29.64*	*95.61*
B 1	Check	**238.2**	119.4	33.7	20.3	64.8	*27.20*	....	....
B 5	Check	**209.5**	99.1	34.9	27.9	47.6	*22.72*	....	....
B 9	Check	**203.3**	90.2	31.8	22.9	58.4	*28.73*	....	....
	Average	**237.8**	**143.2**	**35.4**	**30.0**	**29.2**	**12.27**	....	....
	Average Percentage Gain or Loss Over Checks								
	Low basic sulfate							**49.28**	**79.39**
	High basic sulfate							**59.80**	**66.87**
	Copper-lime dust							**70.99**	**78.26**

The several dusts were applied every week from June 22 to September 8, twelve treatments. With the exception of the last treatment rain fell within two days following the application, removing most of the dust. The first 6 treatments contained arsenic which was omitted on August 3 and thereafter except on August 23 when the basic sulfates with lead arsenate were applied. Lead arsenate and talc were applied 8 times to the checks which was probably more than was needed. A method of weekly applications is a systematic procedure that is apparently unnecessary early in the season except possibly of lead arsenate for insects, but more frequent applications later in the season following rains might prove more effective in controlling blight (Jones). Doran observed some early and late blights and tipburn on August 17 and considerable late blight on September 10. The yield records were determined from the two middle rows of every 4-row section except the one-half outside sections of Field B, of which both rows were taken.

All the dusts reduced the amount of rot, but the low basic sulfate proved slightly the most effective in this respect. The physical characteristics of fungicides are a factor in the flow and economical coverage when applied as a dust. Neither of the basic sulfates was suitable for application in this form, while the copper-lime dust was light, bulky and of good flow.

Apples

A spraying experiment was conducted on Block B of the Station orchard under the supervision of J. K. Shaw and W. A. Cutler, to determine the relative effectiveness of low and high basic sulfates and lime-sulfur in controlling diseases, primarily scab, on McIntosh and Red Astrachan apples, and the amount of injury to foliage and fruit. The basic sulfates (lots 6 and 7) with lead arsenate and raw linseed oil 1.50–0.50 pt.–50 were applied at a concentration of about 0.07 per cent copper and 0.071 per cent arsenic. A standard mixture of lime-sulfur (33°B) and lead arsenate 1.25 gals.–1.50–50 was employed for comparative purposes. The sprays were applied with a Friend power sprayer with 250-gallon tank, under 275 pounds pressure, and Friend guns with 3/32 disc nozzles. In the pre-pink spray (May 2) and pink spray (May 9) the basic sulfates injured the fruit buds a little more than lime-sulfur. In the calyx spray (May 24) the basic sulfates injured the fruit to some extent, as considerable russeting was observed later, but failed to control scab. Lime-sulfur also gave poor control but proved superior to the basic sulfates and caused less injury. The copper sprays mixed well and their adherence was very good (Cutler). Doran made the following observations as to injury and scab on foliage.

Table 11. Relative Effectiveness of Low and High Basic Sulfates and Lime-sulfur in Controlling Scab on McIntosh and Red Astrachan Apples, and the Amount of Injury,—As Shown by the Foliage

Plot	Fungicide	June 14	July 16
1	Low basic sulfate	Leaves yellow and falling badly. Not much scab.	Trees defoliated. Fruit russeted.
2	High basic sulfate	Leaves yellow and falling badly. Not much scab.	Trees defoliated. Fruit russeted.
3	Lime-sulfur	Leaf injury negligible. Not much scab.	No leaf injury. Fruit not russeted.

Doran noted practically no injury to apple foliage from lime-sulfur, but the basic sulfates defoliated the trees seriously and russeted the fruit. The foliage of the Red Astrachan was injured more than that of the McIntosh.

Table 12. Relative Effectiveness of Low and High Basic Sulfates and Lime-sulfur in Controlling Scab on McIntosh and Red Astrachan Apples, and the Amount of Injury,—As Shown by the Yield

Fungicide	Row	Number of trees	Total yield	Yield per tree
			Lbs.	*Lbs.*
	McIntosh			
Low basic sulfate	B	30	228	7.60
High basic sulfate	D	29	117	4.03
Lime-sulfur	F	30	119	3.97
Check			all fruit dropped	
	Red Astrachan			
Low basic sulfate	A	30	700	23.33
High basic sulfate	C	28	673	24.04
Lime-sulfur	E	29	1067	36.79
Check			all fruit dropped	

Evidently the fungicides were not the limiting factor with McIntosh, but may have had more influence with Red Astrachan.

Doran and Bourne made fruit counts on 1851 McIntosh apples from the several plots on October 8, and obtained the following results:

Table 13. Relative Effectiveness of Low and High Basic Sulfates and Lime-sulfur in Controlling Scab on McIntosh, and Amount of Injury,—As Shown by Fruit Counts

Plot	Fungicide	Clean	Scab	Russet
		Per cent	*Per cent*	*Per cent*
1	Low basic sulfate	7.59	55.26	68.73
2	High basic sulfate	23.90	48.66	43.14
3	Lime-sulfur	62.65	28.31	9.44
	Check		all fruit dropped	

None of the fungicides gave proper control of scab on McIntosh apples under the conditions of operation, which indicates that the applications were improperly timed. From the standpoint of clean fruit and a minimum of russet injury, lime-sulfur was superior to basic sulfates on McIntosh that year.

A dusting experiment was conducted on Block A of the Station orchard, under the supervision of J. K. Shaw and W. A. Cutler, to determine the relative effectiveness of low and high basic sulfates, copper-lime dust and lime-sulfur spray in controlling scab on 5 varieties of apples, and the amount of injury to foliage and fruit. The basic sulfates (lots 6 and 7) were mixed with lead arsenate and a free-flowing talc and contained 3.00 per cent copper and 2.00 per cent arsenic. The copper-lime dust was guaranteed to contain 3.94 per cent copper[1] and 2.92 per cent arsenic. A standard mixture of lime-sulfur (33°B) and lead arsenate 1.25 gals.–1.50–50 was employed for comparative purposes. The dusts were applied with a Niagara power duster and the spray with a Friend power sprayer with 250-gallon tank, under 275 pounds pressure, and Friend guns with 3/32 disc nozzles. The trees on plots 1, 3 and 5 received nitrates while those on plots 2, 4 and 6 did not and were less vigorous and had thinner foliage. In the pre-pink dust (May 7) which was delayed nearly a week on account of the duster being out of order, and the pink dust (May 14) the basic sulfates and copper-lime dust seemed to give similar results with very little burning. In the calyx dust (May 24) none of the dusts was effective in controlling scab. The dusts were applied in the morning when there was very little wind but did not adhere as well as expected (Cutler). Doran made the following observations as to injury and scab on foliage:

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[1] Actually tested 4.28%.

Table 14. Relative Effectiveness of Low and High Basic Sulfate Dusts, Copper-lime Dust, and Lime-sulfur Spray in Controlling Scab, and Amount of Injury,—As Shown by the Foliage

Plot	Fungicide	June 14	July 16
0	Check	No burning Scab very severe.	Not much leaf burn. Scab most severe.
1	Low basic sulfate	No burning. More scab than with lime-sulfur.	Not much leaf burn. Scab very severe.
2	Lime-sulfur	No burning. Scab moderate.	Not much leaf burn. Less scab than with dusts.
3	High basic sulfate	No burning. Scab severe on McIntosh.	Moderate leaf burn. Scab very severe.
4	Lime-sulfur	No burning. Much less scab than with dusts.	Not much leaf burn. Scab bad.
5	Copper-lime dust	No burning. More scab than with lime-sulfur.	Not much leaf burn. Scab severe.
6	Lime-sulfur	No burning. Considerable scab on McIntosh.	Not much leaf burn. Less scab than with dusts.

As a whole Doran noted comparatively little injury to apple foliage from either copper dusts or lime-sulfur spray. The high basic sulfate may have been slightly the most injurious. None of the treatments afforded adequate protection to the foliage against scab probably because of too late application and adverse weather conditions. The best control was obtained with lime-sulfur although inconsistent and "bad" on plot 4. Scab was severe or very severe with all dusts and most severe on the check trees. A closer differentiation would require leaf counts which was not attempted. The effect of insects was negligible (Bourne). As all the plots did not receive the same fertilizer treatment the yields were not comparable and are omitted.

Doran and Bourne made fruit counts on 1825 McIntosh apples from the several plots on October 8 and obtained the following results:

Table 15. Relative Effectiveness of Low and High Basic Sulfate Dusts, Copper-lime Dust, and Lime-sulfur Spray in Controlling Scab on McIntosh, and Amount of Injury,—As Shown by Fruit Counts

Plot	Fungicide	Clean	Scab	Russet
		Per cent	*Per cent*	*Per cent*
1	Low basic sulfate	2.50	97.50	2.50
3	High basic sulfate	7.84	91.37	8.24
5	Copper-lime dust	14.44	71.66	20.14
2, 4, 6	Lime-sulfur	27.66	70.29	3.55
0	Check	....	....	....

None of the fungicides gave control of scab on McIntosh apples because of too late application (Shaw). From the standpoint of scab control and a minimum of russet injury, lime-sulfur spray was rather more effective than the copper dusts.

Grapes

Spraying and dusting experiments were conducted in the College vineyard, under the supervision of O. C. Roberts, to determine the relative effectiveness of low and high basic sulfates (lots 6 and 7), Bordeaux 1.17–1.17–50 and a commercial copper-lime-lead arsenate dust in controlling diseases on Worden grapes and the amount of injury to foliage.

The basic sulfates with lead arsenate and linseed oil 1.50–0.83 pt.–50 were applied as sprays at a concentration of 0.07 per cent copper and 0.07 per cent arsenic, the same as Bordeaux 1.17–1.17–50 with lead arsenate 1.50–50. Chemical hydrated lime was employed in preparing the Bordeaux. Oil was used with the arsenic check spray but not with the Bordeaux. The basic sulfates, mixed with lead arsenate and a free-flowing talc, were applied as dusts which contained 3.00 per cent copper and 2.00 per cent arsenic. The commercial dust was guaranteed to contain 3.94 per cent copper[1] and 2.92 per cent arsenic. The arsenical check dust was composed of lead arsenate and talc and contained 2.00 per cent arsenic. The spray was applied under 75 to 100 pounds pressure with a double action, Deming barrel hand-pump equipped with 2 lines of hose to which were attached rods and disc nozzles. The first two applications of dust were made with an American Beauty hand duster which proved unsatisfactory because of its irregular, intermittent discharge. The last application was made with a Peerless duster which gave an even continuous flow.

The fungicides were applied on the following dates and under the weather conditions stated:

June 7—cloudy, humid, 68° Fahr. Spray and dust.
July 16—clear, moderate southwest wind. Spray.
July 18—clear, moderate southwest wind, 85° Fahr. Dust.
August 13—clear, 75° Fahr. Spray.
August 14—clear, humidity somewhat higher than on the 13th, 76° Fahr. Dust.

Doran found a little downy mildew in the vineyard on August 22 and observed traces on the check plot on September 11. No black rot was detected at any time. As there was practically no disease during the season the efficiency of the several fungicides could not be determined. Bourne noted a few leaf hoppers in the vineyard uniformly distributed over the plots.

Doran, Bourne and Roberts made the following observations on September 21 and 25 relative to foliage injury:

Low basic sulfate spray—burn practically the same as for high basic sulfate, adherence good.

High basic sulfate spray—more burn than on check plot, spray residue adhered well to fruit.

Bordeaux—burn less than from basic sulfates, adherence good.

Check—spray burn mild and generally distributed.

Low basic sulfate dust—burn practically the same as high basic sulfate.

High basic sulfate dust—no more burn than on check plot.

The yield had no significance due to pilfering of the fruit and is omitted.

In the practical absence of disease little could be learned of the relative value of the fungicides. The commercial copper-lime-lead arsenate dust was sticky and would not flow freely (Roberts).

Discussion of Results

The results of the four years of field work appear to warrant the following deductions as to the effectiveness of basic copper sulfate in controlling diseases on various garden crops and fruits and the amount of injury likely to ensue.

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[1] Actually tested 4.28%.

Cucumbers—Low basic sulfate spray (0.25 per cent Cu) was equal or superior to Bordeaux (0.25 per cent Cu) in controlling anthracnose and powdery mildew on cucumbers as determined by yield in 1925 and by leaf counts in 1926. Both fungicides appeared to be slightly injurious to the young leaves in 1926. Neither spray (0.26 per cent Cu) nor dust (7.02 per cent Cu) application of high basic sulfate afforded protection under the continuous heavy rains of 1927, although the dust was slightly the more effective. Neither caused injury.

Celery—Low basic sulfate spray (0.25 per cent Cu) was equal to Bordeaux (0.25 per cent Cu) in controlling early and late blights on celery as determined by yield in 1925 and by leaf counts in 1926. Both spray (0.26 per cent Cu) and dust (7.02 per cent Cu) applications of high basic sulfate increased the yield and grade of celery in 1927, but the dust proved the more effective. Low and high basic sulfate sprays (0.24 per cent Cu) were fully equal to Bordeaux (0.24 per cent Cu) and superior to low and high basic sulfate dusts (6.80 per cent Cu) on celery in 1928 as determined by yield, although the experiment has little significance as the plants did not reach marketable size due to adverse weather conditions.

Potatoes—Low basic sulfate spray (0.26 per cent Cu) was not equal to Bordeaux (0.25 per cent Cu) in controlling early and late blights on potatoes, as determined by yield in 1926; nor was high basic sulfate spray (0.25 per cent Cu) in 1927. Tuber rot, however, did not exceed 1 to 2 per cent in either case (Doran). Low and high basic sulfate sprays (0.24 per cent Cu) were not equal to Bordeaux (0.24 per cent Cu) on potatoes in 1928 as determined by yield of grade No. 1 and by reduction in amount of rot. Evidently a spray of 0.24 per cent copper derived from basic sulfate is not fully adequate to prevent late blight and tuber rot on low lands in a wet season. This was true also of Bordeaux on the College farm in the wet season of 1927, when the rot averaged from 20 to 25 per cent by count. With high basic sulfate dust (7.52 per cent Cu), there was about 1 per cent by weight of tuber rot in 1927. There were no checks. Low and high basic sulfate dusts (6.80 per cent Cu) were not equal to a copper-lime dust (7.70 per cent Cu) on potatoes in 1928, as determined by yield of grade No. 1 and by reduction in amount of rot collectively. The low basic sulfate dust, however, in spite of a lower copper content reduced rot rather more than the copper-lime dust.

Fruits—Low basic sulfate sprays (0.13, 0.19 and 0.25 per cent Cu) were not equal to standard lime-sulfur in controlling scab on Baldwin and McIntosh apples in 1926, and injured the foliage and russeted the fruit, especially in the higher concentrations. The injury on the foliage of Monarch plums increased with the concentration, but was not appreciable on the fruit. With mixed high and low basic sulfate sprays (0.06 and 0.19 per cent Cu) and with lime-sulfur, there was about the same percentage of scabby fruit on Baldwin and McIntosh apples in 1927. The dilute spray with linseed oil was no more injurious than lime-sulfur and was reported a promising mixture for apples (Cutler). The concentrated spray killed the buds and injured the leaves. With mixed high and low basic sulfate dusts (2.50 and 5.00 per cent Cu) on McIntosh apples and Bartlett pears in 1927, there were only a few scab spots on McIntosh with the dilute mixture. Both dusts caused a small amount of russet on McIntosh but no foliage injury. The copper content was reported about right (Drain). Low and high basic sulfate sprays (0.07 per cent Cu) were not equal to lime-sulfur in controlling scab on McIntosh and Red Astrachan apples in 1928 as determined by fruit counts on McIntosh, although none of the fungicides gave adequate control, probably because of too late application. The basic sulfates defoliated the trees seriously and russeted the fruit more than lime-sulfur. Low and high basic sulfate dusts (3.00 per cent Cu) and a copper-lime dust (4.28 per cent Cu) were not equal to lime-sulfur in controlling scab on Baldwin, McIntosh, Northern Spy, R. I. Greening and Tompkins King apples in 1928 as determined by fruit counts on McIntosh, although none of the fungicides gave satisfactory control on either fruit or foliage, probably because of too late application. Basic sulfate dusts did not injure the foliage appreciably, but russeted McIntosh apples a little more than lime-sulfur.

The effectiveness of low basic sulfate sprays (0.13, 0.19 and 0.25 per cent Cu) on Moore's early grapes in 1926 could not be determined in the absence of disease. The injury to foliage increased with the concentration but was not appreciable on the fruit (Roberts). The relative effectiveness of spray (0.06 and 0.19 per cent Cu) and dust (2.50 and 5.00 per cent Cu) applications of mixed basic sulfates and of Bordeaux (0.24 per cent Cu) in controlling mildew and black rot on Worden grapes in 1927 could not be determined, as practically no disease developed. The leaves remained green 10 to 14 days longer with basic sulfates than with Bordeaux, and complete defoliation was equally delayed. The dilute dust caused practically no injury to the foliage, the dilute spray a little, the concentrated dust and spray considerable and Bordeaux most of all. With the latter the "burned" condition was decidedly apparent. Low and high basic sulfate sprays (0.07 per cent Cu) and dusts (3.00 per cent Cu) and dilute Bordeaux (0.07 per cent Cu) were applied to Worden grapes in 1928, but their effectiveness could not be determined in the absence of disease. There was some foliage injury without marked differences. The least was probably on the check, followed by the basic sulfate dusts, Bordeaux and basic sulfate sprays.

Low basic sulfate spray (0.25 per cent Cu) was applied to currants, English gooseberry, nine varieties of grapes, tea roses and phlox in 1926 without injury being observed (Brooks). Low basic sulfate spray (0.16 per cent Cu) did not injure rhododendron seedlings in flats (Kinney).

As to supplementary products, Wilkinite proved of little value except possibly to increase visibility. Saponin was of value in increasing wetting and spreading, and raw linseed oil in increasing adhesiveness. The oil was the most promising. It mixed well and the spray residue adhered firmly to the foliage and fruit of apples and grapes (Cutler, Roberts); while on cucumbers, celery and potatoes, oil was not approved (Guba, Cubbon). The dusts with talc as the vehicle distributed well (Guba, Drain) and appeared to have good adherence (Drain).

Summary and Conclusions

1. Commercial basic copper sulfate has proved effective in controlling disease on cucumbers and celery and promising on potatoes, but requires further demonstration on orchard fruits and grapes.

2. A greater "copper" concentration of basic sulfate than of Bordeaux is necessary in some instances to assure equal control, due to the lower dispersion.

3. The low basic sulfate appears to be slightly more effective per unit of copper than the high basic sulfate, probably because the physical condition has averaged better.

4. The concentration necessary in sprays differs widely from that needed in dusts, as the large proportion of inert vehicle in dusts depresses the activity of the fungicide. The following concentrations of basic copper sulfate and of lead arsenate in sprays and dusts are suggested tentatively for field practice.

Crop	Sprays		Dusts	
	Cu	As	Cu	As
	Per cent	*Per cent*	*Per cent*	*Per cent*
Apples	0.05	0.07*	3.50	2.00
Grapes	0.05	0.07	3.50	2.00
Celery	0.30	....	7.50	....
Cucumbers	0.25	0.09**	7.50	4.00
Potatoes	0.30	0.09	7.50	4.00

*1.50—50.
**2.00—50.

5. Basic sulfate is insoluble and slowly available and must be applied at the proper time and concentration to insure protection.

Literature Cited[1]

1. Bell, J. M., and Taber, W. C.
1908. The three-component system—CuO, SO_3, H_2O—at 25°. Jour. Phys. Chem. 12:171–179.

2. ....and Murphy, G. M.
1926. Basic copper at 100°. Jour. Amer. Chem. Soc. 48 (1): 1500–1502.

3. Britton, H. T. S.
1925. Electrometric studies of the precipitation of hydroxides. Pt. IV. Precipitation of mercuric, cadmium, lead, silver, cupric, uranic and ferric hydroxides by the use of the oxygen electrode. Jour. Chem. Soc. [London] 127 (2):2148–2159.

4. ....
1925. An electrometric and phase rule study of some basic salts of copper. Jour. Chem. Soc. [London] 127 (2): 2796–2807.

5. Field, F.
1862. On some of the basic salts of copper. Phil. Mag. and Jour. Sci. (4) 24:123–126.

6. Holland, E. B., Dunbar, C. O., and Gilligan, G. M.
1926. The preparation and effectiveness of basic copper sulphates for fungicidal purposes. Jour. Agr. Research 33:741–751.

7. Kane, R.
1839. Ann. Chim. et Phys. (2) 72:269.

8. Kruger,——.
1924. Jour. Prakt. Chem. 108:278.

9. Nelson, O. A.
1928. Effect of alkalinity on basic cupric sulphates. Jour. Phys. Chem. 32:1185–1190.

10. Pickering, S. U.
1907. The interaction of metallic sulphates and caustic alkalis. Jour. Chem. Soc. [London] 91 (2): 1981–1988.

11. ....
1910. The constitution of basic salts. Jour. Chem. Soc. [London] 97 (2):1851–1860.

12. Proust, J. L.
1800. Recherches sur le cuivre. Ann. Chim. et Phys. (1)32:26–54.

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[1] The original articles were not always available.

13. Reddick, D., and Wallace, E.
1910. On a laboratory method of determining the fungicidal value of a spray mixture or solution. (Abstract) Science (n. s.) 31:798.

14. Sabatier, P.
1897. Compt. Rend. Acad. Sci. [Paris] 125:101.

15. Smith, J. D.
1843. On the constitution of the subsalts of copper. No. 1. On the subsulphates. Phil. Mag. and Jour. Sci. (3) 23:496–505.

16. Vogel, A., and Reischauer, C.
1859. Jahresber. Pharm. 11:3.

17. Williamson, F. S.
1923. Basic copper sulphate. Jour. Phys. Chem. 27:789–797.

18. Young, S. W., and Stearn, A. E.
1916. The basic copper sulphates. Jour. Amer. Chem. Soc. 38 (2):1947–1953.

Publication of this document approved by the Commission on Administration and Finance.
2M-10-'29. No. 7035.

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 255 November, 1929

Studies in Mineral Nutrition

By J. B. Lindsey and J. G. Archibald

It was formerly held that the dairy animal obtained sufficient mineral matter from the roughages and grains consumed. More recently, based on some experimental evidence, this opinion has been questioned, and many have advised the feeding of supplementary minerals in the form of ground bone, ground limestone and the like. In order to get additional light upon the subject, this Station has conducted experiments with growing and mature dairy animals and presents its findings in Part I of this bulletin.

As a part of the work, many determinations were made of the mineral constituents of the grains and roughages fed, and likewise of the amount found in the ordinary roughages grown in different sections of Massachusetts. These analyses are brought together in Part II of this bulletin.

Requests for Bulletins should be addressed to the

AGRICULTURAL EXPERIMENT STATION,

AMHERST, MASS.

STUDIES IN MINERAL NUTRITION

By J. B. Lindsey, Research Professor, and J. G. Archibald, Assistant Research Professor, of Chemistry[1]

Part I. MINERAL SUPPLEMENTS FOR DAIRY COWS

This bulletin is the final report on six and one-half years' investigation on the feeding of mineral matter to dairy cows. Three progress reports[2] have already appeared and to these the reader is referred for detailed conclusions up to the time these reports were published. The results previously reported were obtained from a study of the feeding of tricalcium phosphate in the form of steamed bone meal specially prepared for animal feeding. In brief, the conclusion reached was that the benefit received from adding steamed bone meal to the ration of dairy cows under conditions existent in New England is very slight.

For the past two years (1926–1928) the mineral supplement fed has consisted of a mixture of dicalcium phosphate, sometimes called precipitated bone, and calcium carbonate or limestone, in the respective proportions of four to one.

It has been shown that lambs and goats assimilate dicalcium phosphate considerably better than they do tricalcium phosphate in the form of steamed or calcined bone. It was thought worth while therefore to give the dicalcium phosphate a trial.

Method of Experimentation

The variation from the experimental procedure described in our previous reports, other than the substitution of the dicalcium phosphate for the tricalcium has been a further impoverishment of the mineral content of the basal ration. This has been done by substituting for a portion of the hay larger amounts of dried apple pomace which is quite low in mineral matter. The maximum amount of pomace fed daily to any one cow has been seven pounds. The amount of calcium carbonate fed (1 part in 5 of the mixture) was added to maintain the same ratio between calcium and phosphorus that existed when the steamed bone was fed.

At the commencement of the experiment with dicalcium phosphate (precipitated bone), the herd consisted of 10 milking Holstein cows, 2 milking Jersey cows, 3 Holstein heifers and 1 Jersey heifer. At the conclusion, some old cows having been sold and some heifers having freshened, there were 10 milking Holsteins, 3 milking Jerseys and no heifers. The animals were well housed and received good care, and except in bad weather were turned daily into adjacent sheltered yards for exercise and sunlight. The cows were barn fed during the entire year; the young stock were turned to pasture from approximately May 20 to October 15.

The entire herd was fed on a basal ration of first-cut hay, dried apple pomace and a grain mixture during the entire period of observation except during the summer months, when, in addition, non-leguminous green material in the form of oats, millet and corn was fed in amounts not exceeding 25 pounds daily to any one animal.

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[1] The work at the station barn was carried out by J. R. Alcock, whose faithful attention to his duties contributed to the success of these experiments. A. W. Magoon assisted Mr. Alcock during the latter part of the experiments.

[2] The Value of Calcium Phosphate as a Supplement to the Ration of Dairy Cows. Jour. Agr. Research. Vol. XXXI, pp. 771-791. October 15th, 1925.

Mineral Matter for Dairy Cows. Mass. Agr. Expt. Station Bulletin No. 230. April, 1926.

Mineral Supplements for Dairy Cows. Paper read at the Annual Meeting of the American Society of Animal Production, Chicago, November 26, 1926. Abstracted in Proceedings of that Society for 1926.

The milking cows received daily an average of 17 pounds of hay; 5½ pounds dried apple pomace; 11½ pounds grain mixture; and 23 pounds green feeds.[3] Salt was added to the extent of ¾ pound to each 100 pounds of the grain mixture, and lump salt was always available in boxes in the out-of-door sheds. In addition the so-called mineral cows received daily, mixed with the grain, an average of 8 ounces of the dicalcium phosphate-calcium carbonate mixture. Running water was before the animals at all times. The cows were fed and milked twice daily. The hay, which was grown on the station grounds, was composed of mixed grasses, timothy usually predominating, and generally was of good quality. The average analysis of the feeds was as follows:

	Protein	*Calcium*	*Phosphorus*
Hay	7.58	0.48	0.21
Dried apple pomace	5.29	0.15	0.11
Grain mixture	17.00	0.06	0.54

The apple pomace was weighed into wooden trays daily, moistened, and the grain mixed with it before being fed. The hay and green forage were weighed daily into 4-bushel baskets.

Composite samples of all feeds were taken from each lot purchased. A 5-day composite sample of the milk of each cow was taken monthly. All feeds and milk were submitted to chemical analyses.

Results of the Experiment

The effect of the supplement has been judged by the same criteria as those used in measuring the effect of bone meal, viz.:

1. General appearance and live weight of the cows.
2. Growth of young cows and heifers.
3. Milk yield.
4. Composition of the milk, especially its ash content.
5. Reproduction.

General appearance

As in previous work on mineral supplements, the general condition of the cows has been followed closely, observations being recorded from month to month. In general the cows in both groups have maintained themselves well. A study of the detailed record of their condition at the commencement of the experiment and again at the close shows that the cows receiving the supplement had a slight advantage in this respect (see Table 1).

Live weight

Respecting maintenance of live weight six individuals were mature when the experiment was begun and consequently can be considered from this standpoint. The stage of gestation at the beginning having been noted, the date during the present season when they were at a similar stage has been ascertained and the average of two weighings on consecutive days as near that date as possible has been taken (see Table 2).

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[3] Green feed substituted for a portion of the hay.

Table 1.—Showing Condition of Cows

Cow No.	Age July 1, 1928	Breed	General condition July 1, 1926	July 1, 1928
		Non-Mineral Group		
6	11	Grade Holstein	good	fair
10	13	Grade Holstein	fair	good
15	9	Grade Holstein	very good	good
35	7	Grade Holstein	good	good
42	5	Grade Holstein	excellent	good
43	6	Purebred Jersey	good	excellent
88	3	Grade Holstein	excellent	very good
99	3	Grade Holstein	fair	fair
		Mineral Group		
11	13	Grade Holstein	good	fair
12	11	Grade Holstein	excellent	excellent
22	8	Grade Jersey	fair	good
33	7	Grade Holstein	good	excellent
40	6	Grade Holstein	good	good
71	4	Grade Holstein	fair	good
98	3	Grade Holstein	good	fair
100	3	Grade Jersey	good	excellent

Cows 10 and 11 were sold on August 8, 1927. Age and condition are given for that date.
Cow 42 was slaughtered on January 10, 1928. Age and condition are given for that date.

The mature cows receiving the supplement made a considerable gain in weight during the two years of the experiment, while the other group showed little change. The supplement may have made this difference, but with this number of animals it is unsafe to draw a positive conclusion.

Table 2.—Maintenance of Body Weight in the Mature Cows

Cow No.	Weight on July 1, 1926 *Lbs.*	Weight on a comparable date this season (1928) *Lbs.*	Gain or loss *Lbs.*
		Non-Mineral Group	
6	1270	1300	+30
10	1205	1170	—35
15	1315	1345	+30
Net gain for the group	....	....	+25
		Mineral Group	
11	1275	1300	+25
12	1405	1510	+105
22	700	820	+120
Net gain for the group	....	....	+250

The second weight for Cows 10 and 11 was taken in August, 1927, when they were sold.

Growth of young cows and heifers

Ten of the animals were immature at the commencement of the experiment: six of them young cows (under 5 years of age) and four unbred heifers. In the case of the young cows variations due to variable stage in gestation have been taken into account as with the mature cows. With the heifers unbred when the experiment started, obviously this method could not be used, but three of the four are in an almost identical stage of gestation this season and the fourth is also bred, though not as far advanced, so from that standpoint their weights can be considered comparable (see Table 3).

Table 3.—Growth of Young Cows and Heifers

Cow No.	Weight on July 1, 1926 Lbs.	Weight on a comparable date this season (1928) Lbs.	Gain Lbs.
Young Cows		*Non-Mineral Group*	
35	910	1010	+100
42	1260	1350	+90
43	830	850	+20
Total gain	....	....	**+210**
		Mineral Group	
33	1215	1355	+140
40	900	980	+80
71	955	1345	+390
Total gain	....	....	**+610**
Heifers		*Non-Mineral Group*	
		Weight on July 1, 1928	
88	685	1135	+450
99	570	1140	+570
Total gain	....	....	**+1020**
		Mineral Group	
98	575	1130	+555
100	445	855	+410
Total gain	....	....	**+965**

The final weight of No. 42 was taken in October, 1927. No later weight is available as the cow was in isolation stall.

No. 88 was in a somewhat earlier stage of gestation than the other three heifers.

The presence of one Jersey in each age class (No. 43 in the young cow class, No. 100 in the heifer class) complicates analysis of these weight data somewhat. A truer picture of the case is obtained if the growth increments are presented on a percentage basis (see Table 4).

Table 4.—Percentage Increase in Weight of Young Cows and Heifers

Cow No.	Mineral group	Non-mineral group
33	11.5	....
40	8.9	....
71	40.8	....
35	....	11.1
42	....	7.1
43	....	2.4
Average	**19.9**	**7.0**
Heifer No.		
98	96.5	....
100	92.1	....
88	....	65.7
99	....	100.0
Average	**94.6**	**81.3**

At first glance this looks like a considerable difference in favor of the "mineral" group, but it is discounted by the fact that they average six months younger in the case of the young cows and two months younger in the case of the heifers than the "non-mineral" group. Unfortunately the weights of the groups at identical ages are not comparable due to considerable differences in stage of gestation. If Nos. 43 and 71 be dropped out of the young cow group the others are of identical age, and the difference is seen to be very small, 8.75 per cent increase in the "non-mineral" group as against 10.4 per cent in the "mineral" group. Among the heifers, if No. 88 were of the same age as the other three (4 months younger than she actually is) her rate of increase in weight would in all probability be enough higher to offset the difference of 13.3 per cent actually found. All things considered, the growth of the young animals was probably not materially influenced by the addition of the mineral supplement.

Another angle from which growth records have been viewed is that of weight of the young stock born and reared during the course of the experiment and now in the herd, as compared with the weight of their dams at a similar age. Of the ten animals listed in Tables 3 and 4, two are as large as their dams were at the same age, six are larger, and two are smaller. The grouping in the experiment is as follows:

Mineral supplement		*No mineral supplement*	
Larger than dam	3	Larger than dam	3
Same size	1	Same size	1
Smaller	1	Smaller	1

All are Holsteins and sired by the same bull, except the two which are the same size as their dams were, which are Jerseys. These facts dispose of possible variation due to influence of different sires; and the identical make-up of the two groups is further evidence that the mineral supplement had little, if any, effect on growth.

Milk yield

The average production of the herd has been well maintained all through the experiment. The corrected[4] daily yield per cow for the whole herd and for the two groups is shown in Table 5.

Table 5.—Daily Yield of Milk, Total Solids, and Fat, per Cow

	No. of Cows	Milk *Lbs.*	Total Solids *Lbs.*	Fat *Lbs.*
Whole Herd				
1st year	10	26.47	3.32	1.07
2d year	11	27.59	3.46	1.09
Mineral Group				
1st year	5	25.03	3.14	1.00
2d year	5	25.38	3.25	1.02
Entire experiment	10	25.21	3.20	1.01
Non-Mineral Group				
1st year	5	27.92	3.49	1.14
2d year	6	29.64	3.65	1.15
Entire experiment	11	28.85	3.58	1.14

The "non-mineral" group was somewhat superior to the "mineral" group in production but it would be unwise to conclude from this that the mineral supplement had a detrimental effect in this respect. The probability is that the difference is due to variations in the inherent capacity of the individuals in the two groups to produce milk. An endeavor has always been made to keep the groups as evenly matched in this respect as possible, but due to the impossibility of predicting in advance the performance of a cow, or more especially of a heifer, in any given year, this is a matter which is difficult to regulate in practice. That the endeavor in this particular instance was not successful is evidenced by the figures.

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[4] Corrections for differences in length of lactation and stage of gestation have been made according to the method of Gaines and Davidson, described in Illinois Agr. Expt. Sta. Bulletin No. 272. Corrections for age have not been necessary as the groups were of approximately the same age, and the age of the herd as a whole did not increase, as some older cows were sold and heifers took their places. Corrections for breed are taken care of by including in the corrected summary the total solids and fat produced as well as the total milk yield.

The conclusions that seem justified are two:

(1.) That the low ash ration apparently had no immediate adverse effect on production.

(2.) That the mineral supplement apparently had no immediate favorable effect.

Composition of the milk

The milk from each cow in the herd was sampled for five consecutive days each full month that she was in milk. Total solids and fat have been determined each month during the course of the experiment. Total ash, calcium and phosphorus have been determined every three months.

Table 6.—Composition of the Milk

	Whole Herd	Mineral group	Non-mineral group
Total solids	12.53	12.58	12.53
Fat	3.99	3.96	4.03
Total ash	0.711	0.712	0.710
Ash as per cent of total solids	5.67	5.66	5.66
Calcium	0.121	0.123	0.120
Phosphorus	0.099	0.102	0.097

Expressed as percentage of the liquid milk.

These figures have been corrected for differences in the breed make-up of the groups. Corrections for stage of lactation have not been necessary, as the average stage of lactation at the time the samples were taken was the same in both groups.

The differences between the groups in this respect are seen to be very slight, and while they favor the "mineral" group (except in the fat content) they are not of sufficient magnitude to be of any significance.

Reproduction

Reproductive troubles have not been serious in either group. The average length of time after calving before reappearance of oestrum has been:

Mineral group	38 days
Non-mineral group	45 days

Regarding regularity in recurrence of oestrum the records show the following:

	Good	*Fair*
Mineral group	11	1
Non-mineral group	9	3

The average number of services required to breed has been:

Mineral group	1.13 times
Non-mineral group	1.30 times

Seventy-one per cent of the breedings have been from one service, only one cow in each group giving serious trouble in this respect.

Other irregularities have been:

One premature birth (8 months) in the "mineral" group.

One case of *nymphomania* (chronic buller) in the "mineral" group.

One case of cervicitis (inflammation of the neck of the uterus) in each group.

Three cases of retained afterbirth (two of them in the same cow in successive years) in the "non-mineral" group.

One calf died *in utero* at about the sixth or seventh month stage as a result of cervical and general uterine infection in the dam. This was in the "non-mineral" group.

Apparently the cows that received the mineral supplement were a little closer to normal in their reproductive function than those that did not receive it. They came in heat a little sooner after calving, recurrence of heat was slightly more regular, and they bred a little more readily. Other irregularities were about evenly divided between the two groups. In any case the reproductive troubles have not been greater than are ordinarily encountered in practical herd management.

The condition of the calves at birth and subsequently is also of interest in this connection. Twenty-six calves have been dropped in the herd during the course of the experiment. Classification of these according to group and condition appears below.

	Vigorous	*Good*	*Fair*	*Delicate*
Mineral group	3	9	1	1
Non-mineral group	3	5	4	0

The main difference here is seen to be in the "good" and "fair" groups. The statistics undoubtedly favor the "mineral" group but they need to be examined as to the make-up of the groups with respect to sex and breed, as these determine to a considerable extent the apparent vigor of a calf. Bulls are usually more lusty than heifers; Holsteins are generally more rugged than Jerseys.

Of the four "fair" calves in the "non-mineral" group three were heifers, and the fourth, although a bull, was a Jersey. On the other hand, of the nine "good" calves in the "mineral" group, six were heifers, and three of these heifers were Jerseys. These situations just about offset each other so that the balance is still somewhat in favor of the "mineral" group. It would seem that the cows receiving the mineral supplement produced on the whole somewhat better calves. It must be stated, however, that some very fine calves have come from the cows that have not received the supplement.

Summary and Conclusions

The object of this work has been to determine the value for dairy cows of a mineral supplement consisting of 80 per cent dicalcium phosphate (precipitated bone) and 20 per cent carbonate of lime (ground limestone) added to a ration supposedly deficient in lime. Previous work with tricalcium phosphate in the form of steamed bone meal as a source of lime and phosphorus showed little, if any, advantage in supplying these elements in that form. As dicalcium phosphate is somewhat more soluble and had given better results elsewhere with lambs and goats than the tricalcium phosphate, it was thought worthy of a trial with cows.

A special effort was made to have the basal ration of the cows as deficient in lime as possible. To this basal ration there was added for half of the herd (known as the "mineral" group) sufficient of the phosphate-carbonate mixture to theoretically make good the deficiency. The experiment was carried on for two years with the following results:

1. All the cows in the herd maintained their general condition well. The mature cows that received the mineral supplement maintained themselves slightly better in this respect than did those not receiving the supplement. They also made a considerable gain in weight while the "non-mineral" group showed little change.

2. The mineral supplement had little, if any, effect on the growth of the young cows and heifers.
3. The low ash ration apparently had no adverse effect on milk production, and the mineral supplement apparently had no favorable effect.
4. The composition of the milk was not significantly affected.
5. Reproductive troubles were not serious in either group, but the cows receiving the mineral supplement were a little nearer normal and produced on the whole somewhat better calves than did those that did not receive it.
6. It must be emphasized that none of the differences between the groups was sufficiently striking to warrant as a general recommendation the use of the dicalcium phosphate-calcium carbonate mixture.

Where cows are average producers (5000–8000 pounds), and where they are fed normally *on good quality roughage* the need of a mineral supplement is not indicated. For heavy producers (10,000 pounds and upwards) it is probably good insurance to supply supplemental lime and phosphorus, but the efficacy of such a practice is by no means well established.

It has been nothing short of amazing to note the persistency with which the cows devoted to this study have maintained their milk production and for the most part their own well-being on low ash rations over a period of years. If these cows which average over 9000 pounds of milk yearly (several of them being 11,000 to 12,000 pound cows) can make such a showing on abnormal rations, it seems reasonable to infer that the average New England cow on good quality roughage must have a considerable margin of safety as far as minerals are concerned. It seems probable that the mineral problem is a regional or local one. If soils on which roughages are grown are so deficient in lime or phosphorus as to produce feeds low in these ingredients, then the addition of a mineral supplement may prove helpful. It is not believed that such conditions with respect to calcium prevail in New England, while possible deficiencies of phosphorus in our roughages are made good by the liberal grain feeding practiced in this section of the country.

Part II. MINERAL MATTER IN CATTLE FEEDS

In order to ascertain the mineral content of the ordinary roughages grown by farmers in Massachusetts, numerous samples of hay and corn silage—the two staple coarse feeds—were collected with the aid of the county agents from different sections of the State, and analyzed for the most important mineral constituents. It was surprising how few analyses were on record, especially of the calcium content of cattle feeds. In the following pages are given the results, together with such brief comments as seem necessary.

Mineral Matter in Massachusetts Roughages[1]

Sixty-eight samples, including thirty-two of hay, twenty-four of corn silage and twelve miscellaneous roughages were collected and analyzed. They were obtained from thirty-three farms in twenty-nine towns, located in eleven counties.

The results, in order to be comparable, are expressed in the case of hay on a 10 per cent water basis and in the case of silage on a 78 per cent water basis, and also on an elemental basis; that is, as the elements, calcium (Ca) and phosphorus (P) instead of as the oxides CaO and P_2O_5, etc. In Table 1 they are arranged on the basis of location in the State, beginning with Barnstable County in the southeast and continuing to Berkshire County in the west.

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[1] All of the analytical work was done by H. D. Haskins and L. S. Walker of the Control Service. The methods followed were those of the Association of Official Agricultural Chemists.

Table 1.—Mineral Matter in Massachusetts-Grown Roughages (Per Cent)

Lab. Number	Total Ash	Calcium (Ca)	Phosphorus (P)	Magnesium (Mg)	Potassium (K)	Sulfur (S)	Remarks
				(A) Hays—calculated with 10% water			
540	5.29	0.53	0.15	0.25	1.51	0.09	Mixed grasses, rather coarse
599	5.02	.29	.15	.13	1.74	.11	Timothy and brown top, fair quality
571	5.49	.37	.17	.19	1.38	.13	Mixed grasses, fine
564	3.54	.29	.14	.12	1.03	.05	Timothy and redtop
562	5.53	.35	.18	.19	1.22	.11	Mixed grasses, very fine
541	5.83	.67	.20	.25	1.78	.08	Largely timothy, rather coarse
576	5.35	.44	.17	.20	.91	.09	Timothy, blue grass and clover
578	5.06	.37	.13	.13	1.14	.11	Mixed grasses, fair quality
582	5.35	.31	.13	.13	1.02	.09	Mixed grasses, fair quality
575	5.34	.23	.19	.13	1.54	.13	Timothy, poor quality
543	4.73	.23	.19	.17	.81	.12	Probably salt marsh, very fine
568	6.46	.27	.25	.10	2.44	.10	Mostly timothy, coarse
537	4.93	.62	.16	.28	.64	.11	Medium quality
597	5.01	.34	.16	.12	.90	.13	Mixed grasses, fair quality
587	4.64	.33	.16	.11	1.41	.09	Mixed hay, good quality
580	5.08	.41	.14	.14	1.39	.11	Clover and timothy, coarse
595	3.77	.40	.09	.13	.69	.14	Timothy, redtop and clover
573	5.59	.41	.13	.17	.94	.16	Timothy and clover, medium
585	3.97	.31	.13	.19	.63	.14	Timothy and brown top
551	4.90	.38	.22	.17	1.52	.17	Timothy, very coarse
593	4.34	.34	.14	.12	1.30	.08	Timothy, first quality
555	4.91	.46	.13	.33	1.07	.14	Mixed grasses, fine
557	5.39	.35	.17	.26	1.69	.14	Mixed grasses, quite fine
558	5.29	.72	.13	.18	1.37	.06	Mixed grasses, very coarse
553	6.34	.55	.19	.35	1.73	.22	Mixed grasses, fine
566	5.59	.65	.17	.15	1.48	...	Timothy and some alsike, very coarse
560	5.46	.64	.14	.24	1.35	.09	Mixed grasses, quite fine
591	3.71	.29	.12	.12	1.12	.09	Timothy, good quality
534	5.87	.49	.22	.18	1.93	.07	Largely timothy, very coarse
546	3.68	.31	.13	.18	.95	.11	Mostly timothy, coarse
548	4.26	.44	.13	.22	.75	.10	Mostly timothy, coarse
550	4.40	.41	.13	.17	.86	.16	Fine, fair quality

Table 1 (Continued)—Mineral Matter in Massachusetts-Grown Roughages (Per Cent)

Lab. Number	Total Ash	Calcium (Ca)	Phosphorus (P)	Magnesium (Mg)	Potassium (K)	Sulfur (S)	Remarks
(B) Corn Silage—calculated with 78% water							
539	1.20	0.06	0.04	0.06	0.30	0.02	Fair quality, no ears
542	.97	.10	.05	.06	.20	.01	Well-eared but rather sour
577	1.08	.05	.04	.03	.30	.01	Good quality, sweet and well-eared
579	1.13	.09	.05	.05	.25	.02	Good quality, sweet and well-eared
583	1.14	.08	.03	.04	.25	.02	Few ears, otherwise excellent. From silo filled early
584	.99	.05	.04	.04	.22	.01	Well-eared but otherwise very inferior. From silo filled late
544	1.19	.06	.04	.06	.28	.02	Poor quality, bad odor
598	1.38	.05	.04	.03	.32	.02	Excellent, sweet and well-eared
581	1.34	.07	.04	.04	.34	.02	Few ears, otherwise good
598	1.63	.06	.03	.04	.49	.02	Few ears, otherwise good
574	1.39	.06	.04	.04	.20	.02	Well-eared but rather moldy
586	1.51	.05	.04	.02	.46	.02	No ears, otherwise excellent
536	.97	.07	.04	.06	.20	.02	Excellent, well-eared
594	1.69	.15	.05	.06	.43	.02	Poor quality, no ears, badly decomposed
556	.88	.05	.05	.05	.18	.02	Excellent, sweet and well-eared
559	.88	.04	.04	.03	.23	.02	Good quality, sweet and well-eared
554	1.44	.05	.03	.09	.26	.02	Good quality, sweet and well-eared
567	1.00	.05	.04	.04	.22	.01	Good quality, sweet and well-eared
561	1.77	.07	.05	.04	.27	.01	Fair quality, few ears
592	1.50	.12	.04	.07	.36	.02	Few ears, immature, otherwise good
535	1.08	.08	.04	.08	.17	.02	Few ears, otherwise good
545	1.01	.07	.04	.09	.21	.02	Fair, no ears, some mold
547	1.08	.09	.04	.11	.18	.04	Poor, no ears, moldy
549	1.35	.06	.05	.09	.22	.02	Few ears, moldy

Table 2.—Average of All Samples

Material	State of Material	Water	Calcium (*Ca*)	Phosphorus (*P*)	Magnesium (*Mg*)	Potassium (*K*)
		Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*
			.26–.72	.10–.28	.11–.39	.70–2.71
Hay	Dry matter basis	none	0.46	0.18	0.20	1.40
Hay	Natural moisture	10	0.41	0.16	0.18	1.26
			.20–.69	.12–.24	.10–.49	.75–2.23
Silage	Dry matter basis	none	0.36	0.20	0.25	1.24
Silage	Natural moisture	78	0.08	0.04	0.06	0.27

The figures above the line refer to minimum and maximum percentage, and the figure below the line represents the average.

Comments on the analyses of hay

Calcium and phosphorus are the minerals most likely to be deficient in the ration of the dairy cow. In cases where calcium falls below 0.30 per cent, it might be considered deficient. Whether this represents the normal conditions on the particular farms where the samples were taken, it is not possible to state. The average of 0.41 per cent is believed to be normal and sufficient for the purposes of nutrition. A few samples show a low phosphorus percentage, namely, 0.10–0.14 per cent, but the average of 0.16 probably is satisfactory. There is not much danger of a phosphorus deficiency in New England for the reason that considerable grain is fed, which is high in this ingredient. The magnesium and potassium are believed to be ample in amount, although there are wide differences in the potash percentage (0.75 to 2.23). Hays containing the lesser amounts may have been grown on soils naturally low in available potash.

Comments on the analyses of silage

Compared with hay, on a dry matter basis the silages average rather less calcium (0.36 compared with 0.46 for hay) and potassium (1.24 compared with 1.40 for hay) and about the same percentages of phosphorus and magnesium. Individual samples vary widely, depending probably upon available soil mineral constituents and stage of growth. The data show no pronounced deficit of mineral constituents.

Relation of botanical composition of the hay to the ash content

Twelve samples of hay were all or nearly all timothy; twenty were mixed grasses.

	Calcium	*Phosphorus*	*Magnesium*	*Potassium*
Timothy	.49	.19	.18	1.55
Mixed grasses	.50	.17	.22	1.31

Differences of importance are not noticed, although rather less calcium is found in the timothy than in the mixed grasses.

Relation of number of ears in silage to ash content

Eleven of the samples were well-eared; thirteen had few or no ears.

	Calcium	*Phosphorus*	*Magnesium*	*Potassium*
Not eared	.37	.19	.28	1.39
Well-eared	.28	.19	.21	1.07

These figures confirm what is already known with respect to the variation in the ash content after the corn plant matures; namely, that with the exception of the phosphorus, all the ash constituents diminish relatively as the plant approaches maturity. The phosphorus remains constant or nearly so because the tendency to diminish, which is characteristic of the other constituents of the ash, is offset by the fact that the seed contains a much higher percentage of phosphorus than do the other parts of the plant.

Mineral Matter in Miscellaneous Roughages and Concentrates

In addition to the mineral analyses of roughages collected in various sections of Massachusetts, numerous mineral analyses have been made of different roughages and concentrates used in connection with our experiments in mineral nutrition during the last few years. Most of the roughages were grown upon the experiment station and college farm or on farms near by. The concentrates came from different sections of the country. Those marked "Feed Control" were collected in this State by the station inspection service. In addition, for the sake of comparison, other sources were drawn upon. Those marked "M. and L." refer to Mentzel and Lengerke, the German tabulation, and those marked "Forbes" were taken from Bulletin 255 of the Ohio Experiment Station and were made under the direction of E. B. Forbes.

The percentages of only the most important mineral elements are presented, namely, calcium, phosphorus, magnesium, potassium and sulfur. Silica, while not stated, was found in amounts varying from one to two or more per cent in roughages and grain hulls and less than one per cent in most concentrates. Iron and aluminum were present in quite small amounts as well as traces of sodium. The legume roughage contains the most calcium, followed by the non-legumes, while not much more than .1 to .2 per cent is to be found in the concentrates; the latter, on the other hand, contain considerable amounts of phosphorus. The roughages contain liberal amounts of potassium, and most concentrates contain fair to liberal quantities. Both roughages and concentrates have reasonable amounts of magnesium, although the amount of this element varies considerably in different plants, grains and by-products.

The variations in the percentages given by the different authorities as a rule are not marked. By-products are likely to vary in composition to a limited extent. In general it may be said that the roughages furnish most of the calcium and the concentrates most of the phosphorus.

Table 3.—Mineral Matter in Miscellaneous Cattle Feeds (Per cent)

Material	Source	Total Ash	Calcium *Ca*	Phosphorus *P*	Magnesium *Mg*	Potassium *K*	Sulfur *S*	No. of lots
	(A) *Roughages—Hays.*	(*calculated with 12% water*)						
Alfalfa	College Farm	7.59	1.08	0.24	0.21	2.02	0.20	3
Mixed grasses, timothy predominating	College Farm	5.10	0.49	0.20	0.16	1.36	0.15	14
Oat straw (purchased in market)		8.47	0.36	0.13	...	1.35	...	2
Rowen (second cut of hay fields)	College Farm	10.15	0.61	0.27	...	1.43	...	2
	(B) *Roughages—Green.*	(*calculated with 80% water*)						
Corn plant (milk to late glaze)	College Farm	1.10	0.06	0.05	...	0.28	...	3
Hungarian grass	College Farm	3.16	0.20	0.08	...	0.56	...	2
Barnyard millet (bloom)	College Farm	2.14	0.10	0.06	...	...	...	3
Oats (in milk)	College Farm	2.77	0.10	0.08	...	0.58	...	3
Oats and peas (oats in milk)	College Farm	2.26	0.07	0.09	...	...	...	3
Sorghum	College Farm	1.48	0.16	0.06	...	...	...	...
Soy bean fodder	College Farm	2.52	0.28	0.06	...	0.28	...	4
Sudan grass	College Farm	1.85	0.10	0.05	0.07	0.61	0.04	4
Sweet clover	College Farm	2.08	0.29	0.09	0.06	0.59	0.12	1
Vetch (winter)	College Farm	3.46	0.44	0.08	0.05	0.53	0.05	1
	(C) *Concentrates.*	(*calculated with 10% water*)						
Alfalfa meal	Feed Control	8.26	1.21	0.17	0.24	1.91	0.24	7
Apple pomace (dried)	Manufacturer	1.61	0.10	0.08	...	0.49	...	1
Barley feed	Feed Control	3.71	0.03	0.40	0.16	0.60	0.05	2
Beet pulp (plain)	Feed Control	3.16	0.65	0.07	0.24	0.17	0.17	15
	Feed Control	...	1.07	0.10	...	0.17	...	1
	M. and L.	3.43	0.90	0.05	0.13	0.42	...	...
	Forbes	2.89	0.66	0.06	0.25	0.32	0.13	
Beet pulp (molasses)	Feed Control	5.92	0.45	0.06	0.13	1.60	0.38	2
Brewers' grains (dried)	Feed Control	3.38	0.13	0.44	0.14	0.05	0.04	6
	Feed Control	...	0.33	0.45	...	0.03	...	8
	M. and L.	4.04	0.39	0.61	0.25	0.13	...	
	Forbes	2.66	0.15	0.45	0.15	0.17	0.38	

Cocoanut meal	Manufacturer	6.25	0.19	0.62	...	1.99	...	3
	Feed Control	...	0.20	0.61	...	1.80	...	4
	M. and L.	5.40	0.44	0.51	0.24	1.68	0.07	..
Corn bran	Feed Control	2.96	0.05	...	0.25	0.73	0.07	1
	M. and L.	0.62	0.03	0.11	0.08	0.14	...	..
	Forbes	1.20	0.03	0.14	0.08	0.37	0.11	..
Corn germ meal	Manufacturer	3.55	trace	0.80	...	...	...	1
Corn meal	Feed Control	1.13	trace	0.20	0.09	0.27	0.01	16
	M. and L.	1.29	0.02	0.23	0.12	0.33	trace	..
	Forbes	1.26	0.01	0.27	0.11	0.36	0.15	..
Cottonseed feed	Feed Control	4.41	0.14	0.63	0.38	1.20	0.12	1
	Feed Control	...	0.27	0.80	...	1.16	...	9
Cottonseed meal	Feed Control	5.94	0.12	0.70	0.56	1.46	0.08	82
	Feed Control	...	0.13	1.13	...	1.31	...	28
	M. and L.	6.65	0.19	1.20	0.62	1.33	0.04	..
	Forbes	6.87	0.26	1.33	0.54	1.63	0.49	..
Red dog flour	Feed Control	1.68	0.08	0.32	...	..*	...	7
	Feed Control	...	0.14	0.79	...	0.68	..	3
	Forbes	3.74	0.12	0.84	0.29	0.38	0.25	..
Gluten feed (one analysis each of 5 different brands)	Feed Control	3.56	0.13	0 52	0.26	0.56	0.05	26
	Feed Control	...	0.13	0.50	...	0.49	...	18
	Forbes	3.11	0.24	0.53	0.22	0.24	0.58	..
Gluten meal	Feed Control	1.12	0.01	0.37	0.03	0.02	...	15
	Feed Control	...	0.13	0.31	...	0.03	...	1
Hominy feed	Feed Control	2.92	trace	0.60	0.24	0.67	0.02	58
	Feed Control	...	0.29	0.50	...	0.45	...	27
Linseed meal	Feed Control	5.74	0.34	0.95	...	1.31	...	2
	Feed Control	...	0.27	0.90	...	1.26	...	13
	M. and L.	5.17	0.32	0.73	0.50	1.06	0.10	..
	Forbes	5.79	0.36	0.71	0.49	1.10	0.41	..
Oat feed	Feed Control	5.89	0.08	0.14	0.07	0.50	0.14	3
	Feed Control	...	0.41	0.19	...	0.59	...	9

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*Amount of potassium varied in different samples from .14% to .68%, doubtless due to differences in the milling process.

Table 3 (Continued)—Mineral Matter in Miscellaneous Cattle Feeds (Per cent)

Material	Source	Total Ash	Calcium *Ca*	Phosphorus *P*	Magnesium *Mg*	Potassium *K*	Sulfur *S*	No. of lots
Oats, ground	Feed Control	3.29	0.07	0.32	...	0.41	...	8
	M. and L.	3.02	0.13	0.39	0.10	0.43	0.04	..
	Forbes	3.34	0.10	0.39	0.12	0.41	0.19	..
Peanut meal	Feed Control	5.54	trace	0.37	0.29	1.03	0.10	1
	Manufacturer	5.70	0.19	0.75	...	1.05	...	1
	Feed Control	...	0.41	0.67	...	1.27	...	1
	M. and L.	2.05	0.09	0.10	0.04	1.04	0.20	..
Rye feed	Feed Control	3.20	trace	0.59	0.23	0.83	0.04	..
Skim milk powder	Manufacturer	7.58	1.21	0.92	...	1.62	...	2
	Forbes	6.45	1.21	0.88	0.14	1.14	0.32	..
Wheat seed	Forbes	1.68	0.05	0.39	0.13	0.53	0.20	..
Wheat bran	Feed Control	6.26	0.15	1.31	...	1.44	...	1
	Feed Control	...	0.21	0.94	...	1.56	...	..
	M. and L.	4.65	0.10	1.02	0.44	1.04	0.04	..
	Forbes	6.06	0.13	1.11	0.53	1.31	0.27	..
Wheat middlings (standard)	Feed Control	4.38	trace	0.95	0.36	0.95	0.05	32
	Feed Control	...	...	1.10	...	1.18	0.13	21
Wheat middlings (flour)	Feed Control	3.84	trace	0.41	0.33	0.85	trace	4
	Forbes	4.17	0.10	0.88	0.39	1.04	0.03	..

Publication of this document approved by the Commission on Administration and Finance.

4M-11-'29. No. 7188.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 256 November, 1929

The Cost of Government in Massachusetts

1910-1926

By Hubert W. Yount and Ruth E. Sherburne

The rapid increase in demands for public service, together with the resulting increase in taxes, has placed a severe strain on farmers in many Massachusetts towns. This study analyzes the costs of public service in such towns compared with larger towns and cities, and points out the more important handicaps under which small towns operate.

Requests for bulletins should be addressed to the

AGRICULTURAL EXPERIMENT STATION

AMHERST, MASS.

SUMMARY

1. Total public expenditures for State and local purposes increased from $122,000,000 in 1910 to $357,000,000 in 1926, or 192 per cent.

2. Expenditures per capita in towns having less than 1000 population increased 265 per cent between 1910 and 1926, as compared with a general increase for the state of only 130 per cent.

3. In terms of purchasing power, public expenditures per person in 1926 were not more than 55 per cent above 1910.

4. The three principal causes of the increase in public expenditures are the rise in the price level, the increase in government services, and the growth of population.

5. Approximately five-sixths of total expenditures are for local town or city purposes.

6. Interest and debt payments required one-eighth of total expenditures in 1926. Payments for these purposes are not important in most small towns.

7. Schools and roads take more than 40 per cent of total expenditures, and the percentage has been increasing gradually.

8. The construction and maintenance of highways takes about one-sixth of the total budget of Massachusetts, State and local. In 1926 highways took 51 per cent of total expenditures in towns with less than 500 population, but less than 13 per cent in cities.

9. One-fourth of total expenditures is for education. The importance of this item tends to vary inversely with the size of the town; in towns with less than 1000 population, expenditures for education average more than 40 per cent of the total.

10. Education in small towns costs more per person, more per pupil, and more per $1000 of assessed valuation than in larger towns and cities, and frequently the service received is distinctly inferior.

11. State financial aid to small towns for education and highways is partly overcoming the financial handicap of rural communities.

12. Only 5 per cent of the expenditures per person in towns with less than 1000 population are for charity, public health and recreation. The percentage tends to increase with the size of the town or city, certain cities running as high as 25 per cent.

13. The cost per person for general government is twice as much in small towns under 1000 population as in large towns and cities.

14. Legal requirements imposed upon towns, while responsible in part for the increase in expenditures, have been offset by various forms of State aid.

15. About 70 per cent of the total cost of government is met by taxes. The remainder is paid from departmental earnings and receipts, gifts and grants, and from borrowed funds.

16. Taxes on real estate have been increasing somewhat faster than other taxes. This is particularly marked in rural towns in which the tax burden is carried largely by real estate.

17. The tax per $1000 of assessed valuation, i. e., the tax rate, has increased much more rapidly in farm towns than in manufacturing towns and cities.

18. For the state as a whole, borrowing does not appear to be excessive, but certain larger towns and cities are approaching the danger point on the basis of ordinary criteria of safety.

THE COST OF GOVERNMENT IN MASSACHUSETTS, 1910-1926[1]

By Hubert W. Yount, Assistant Professor, and Ruth E. Sherburne, Research Assistant, in Agricultural Economics

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INTRODUCTION

In common with other states, public expenditures in Massachusetts have been increasing rapidly in recent years. The necessity of finding revenue to meet the increased cost of the different services performed by state and local governments as well as to support many new activities has focused attention on problems of public finance. This study was begun in 1925 in cooperation with the Bureau of Agricultural Economics of the United States Department of Agriculture as one of a series of similar studies in several states. The purposes of this investigation were:

1. To show the increase in State and local expenses since 1910.
2. To show the increase in expenditures for different purposes.
3. To analyze the causes of increasing expenditures for State and local purposes.
4. To show how revenues have been obtained to meet increasing expenditures.
5. To analyze and compare the costs of similar governmental activities in farm and urban communities.
6. To compare benefits received from public expenditures with the costs in farm and urban communities.
7. To determine to what extent state financial aid is reducing the tax burdens in agricultural towns.

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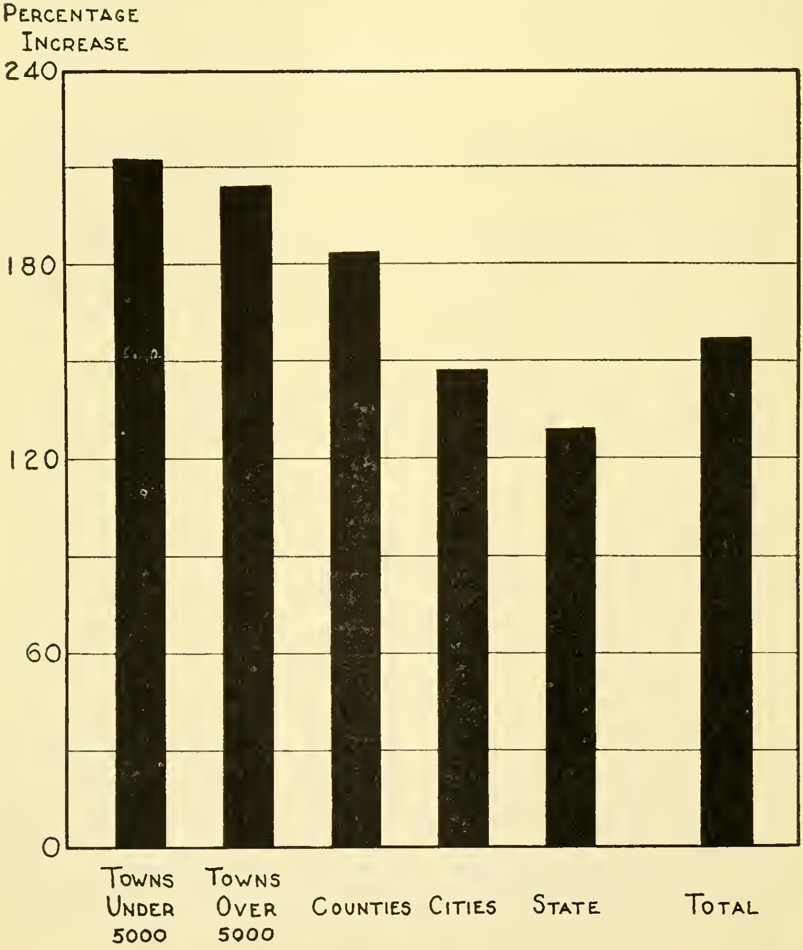
[1] This is the second of two studies dealing with taxation and public finance in Massachusetts, carried on in cooperation with the Bureau of Agricultural Economics of the United States Department of Agriculture. The first study was published in April, 1927, as Experiment Station Bulletin 235, "Farm Taxes and Assessments in Massachusetts." This was concerned primarily with problems of assessment and the relation of the individual to local taxation. The authors are indebted to R. Wayne Newton, formerly Associate Agricultural Economist with the Bureau, for suggestions and criticisms of the present study; also to Professor D. W. Sawtelle, formerly of the Department of Agricultural Economics, Massachusetts Agricultural College, for material service in certain of the tabulations and in preparation of the charts.

The Unit of Government in Massachusetts

Taxes are levied and funds are spent by three different civil units in Massachusetts. These are the central state government, counties, and cities or towns. The local city or town is the most important unit of government, carrying on many of the functions performed by counties in other sections of the country. The county is relatively unimportant, since county activities are limited to the support of certain courts, the recording of land titles, a small amount of highway construction, the support and administration of training schools for habitual truants and other school offenders, and other minor functions. Certain counties also support agricultural high schools in whole or in part, and a few counties maintain hospitals for the care of tubercular children.

CHART 1. Increase in Public Expenditures for the State, Counties and Identical Cities and Towns, 1912-1926. (Expressed in Percentages.)



The more important functions performed by the city or town are the assessment and collection of poll and property taxes, the maintenance of local schools, the construction and maintenance of local highways, the administration of poor relief, and the control of local public health and sanitation.

The more important functions of the central state government[2], in addition to the usual legislative and executive or police functions, are the construction and maintainance of highways, the supervision and support of educational activities, the care of the feeble-minded and insane, and the maintenance of correctional institutions. The State also levies and collects various corporation taxes and the state income tax, and distributes the proceeds to towns and cities as provided by law.

Table 1.—Total Annual Expenditures in Massachusetts, by Jurisdictions, 1910-1926.[1]

(Thousands of dollars)

Year	Central State Gov't	Counties[2]	Towns Under 5,000	Towns Over 5,000	Cities	**Total**
1910	$19,093	$ 3,642	$ 6,127	$17,406	$ 76,025	**$122,293**
1911	19,922	3,406	6,341	17,272	78,487	**125,428**
1912	21,774	3.482	9,733	18.196	85,581	**138,766**
1913	26,208	3.795	10.804	19.233	94,150	**154,190**
1914	29,163	4,012	9,263	21,227	99,088	**162,753**
1915	27,338	4.007	10,154	21.130	100,395	**163,024**
1916	28,629	4.346	10,134	21.801	101,154	**166,064**
1917	34,122	4,760	10,685	23,080	107,950	**180,597**
1918	38,100	5.510	10,466	22.564	110.344	**186,984**
1919	55,213	5,536	12,904	26,155	127.262	**227,070**
1920	46,716	6,901	16,005	32,752	150,350	**252,724**
1921	44,174	10,343	17,600	36,423	167,991	**276,531**
1922	45,274	9,217	18.844	38.359	173,723	**285,417**
1923	46,385	9,025	20,343	41.439	186.683	**303,875**
1924	48,076	9,210	21,293	49.200	203,828	**331,607**
1925	47.979	10,132	22.630	49.974	206.627	**337,342**
1926	49,802	9,870	23,968	53,416	219,915	**356,971**

[1] Expenditures for all purposes, including new construction.

[2] Payments on debt not available.

THE INCREASE IN PUBLIC EXPENDITURES[3]

From 1910 to 1926, reported annual expenditures for State and local purposes increased from $122,293,000 to $356,971,000, or 192 per cent. (Table 1) However, the data are not strictly comparable before 1912, since a few small towns did not report until that year. The relative increase in expenditures for the State and for counties, cities and towns from 1912 to 1926 is shown in Table 2 and in Chart 1. In official reports, municipalities are classified as cities, or as towns over or under 5,000 population, according to the most recent census. When a large town becomes a city or when a town

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[2] Hereafter called State.

[3] Data on public expenditures have been taken from the following sources:

State expenditures: 1910-1922, Annual Reports of the State Auditor, Mass. Pub. Doc. 6; 1923-1926, Annual Reports of the Commission on Administration and Finance, Mass. Pub. Doc. 140.

County expenditures: 1910-1926, Annual Reports on the Statistics of County Finances, Mass. Pub. Doc. 29.

Town and city expenditures: 1910-1926, Annual Reports on the Statistics of Municipal Finances, Mass. Pub. Doc. 79.

Table 2.—Increase in Expenditures, by Jurisdictions, 1912-1926.

Jurisdiction	*Increase Per cent*	*Increase for Identical Towns and Cities as Classified in 1912 Per cent*
Central State Gov't.	228.7	
Counties	283.5	
Cities	257.0	247.3
Towns over 5,000	293.6	304.1
Towns under 5,000	246.3	311.7
Total	**257.2**	

grows to more than 5,000 population, expenditures are reported under the new classification. Therefore the annual figures for the three groups are not always comparable. From 1910 to 1926 the number of cities increased from 33 to 39; towns over 5,000 population increased from 71 to 79; while towns under 5,000 population decreased from 249 to 237.

In order to show the true increase in expenditures for each group, tabulations were made according to the classification of cities and towns in 1912. The second column in Table 2 is the more significant since it shows the increase in expenditures for groups of identical cities and towns.

From the table it will be seen that total expenditures increased two and one-half times from 1912 to 1926, while town expenditures trebled. The increase was greatest for small towns, and least for the State. The percentage increase for counties, while large, is not significant as counties spend less than three per cent of the total. (Table 2)

Increase in Expenditures Per Capita

Due to the changes within the municipal groups, increases in expenditures per capita are more significant than increases in totals. The increase in expenditures per capita for each group from 1910 to 1926 is shown in Table 3.

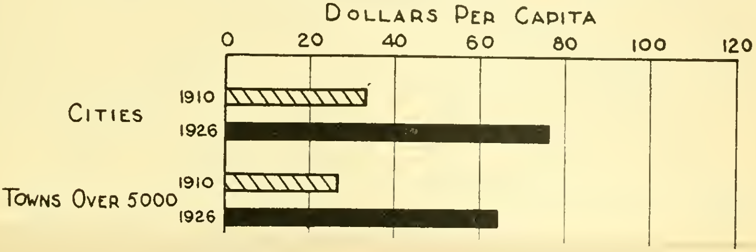
Table 3.—Total Expenditures per Capita.

Jurisdiction	*1910*	*1926*[1]	*Increase Per cent*
Central State Gov't.	$ 5.67	$12.02	*112.0*
Counties	1.08	2.38	*120.4*
Cities	33.11	75.58	*128.3*
Towns over 5,000	26.64	64.48	*142.0*
Towns under 5,000	19.68	59.04	*204.6*
Towns under 1,000	18.82	68.59	*264.5*
Total for the State	**37.51**	**86.14**	**129.6**

[1] On the basis of 1925 population according to the State Census.

On this basis the cost of government has increased a great deal more in small towns than in the larger towns and cities. In a general way, expenditures per capita have tended to increase in inverse relation to the size of the town. This is shown graphically on Chart 2. Expenditures by the State and by counties have increased relatively less than for any other group.

CHART 2. Total Expenditures per Capita for All Purposes and for Local Purposes in Cities and Towns, 1910 and 1926, and the Percentage Increase.



CORRECTION

ssachusetts Agricultural Experiment Station Bulletin 256.

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e title and column headings of Table 2 on page 172 should be:

Table 2. -- Expenditures by Jurisdictions, 1926
(Percentages of 1912)

Jurisdiction	Total as Reported	For Identical Towns and Cities as Classified in 1912

about one-tenth as much as cities.

Approximately one-sixth of the total expenditures were made by the State and counties for general puposes, while five-sixths were for local town or city purposes.

The Relation between Population and Expenditures Per Capita

Table 4 shows total expenditures per capita for towns and cities, grouped according to population, for the years 1907, 1912, 1917, 1922 and 1926. Substantial differences will be noted between groups each year. However, a change has taken place in the relation of population to expenditures per person. Until 1917, there was a fairly distinct tendency for expenditures per capita to bear a direct relationship to population, that is, for expenditures per capita in large

Table 2.—Increase in Expenditures, by Jurisdictions, 1912-1926.

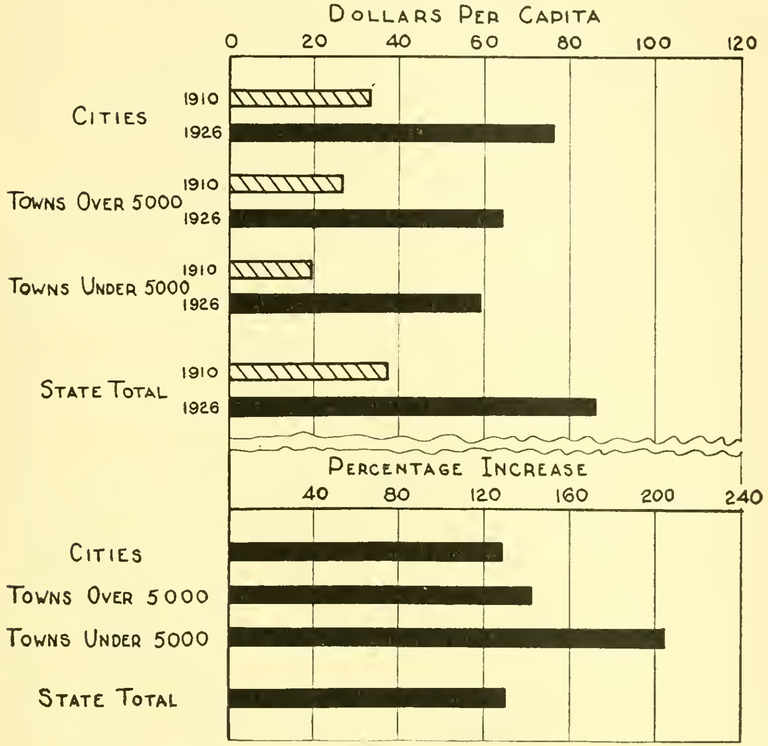
Jurisdiction	*Increase Per cent*	*Increase for Identical Towns and Cities as Classified in 1912 Per cent*
Central State Gov't.	228.7	
Counties	283.5	
Cities	257.0	247.3
Towns over 5,000	293.6	304.1
Towns under 5,000	246.3	311.7

			Per cent
Central State Gov't.	$ 5.67	$12.02	*112.0*
Counties	1.08	2.38	*120.4*
Cities	33.11	75.58	*128.3*
Towns over 5,000	26.64	64.48	*142.0*
Towns under 5,000	19.68	59.04	*204.6*
Towns under 1,000	18.82	68.59	*264.5*
Total for the State	**37.51**	**86.14**	**129.6**

[1] On the basis of 1925 population according to the State Census.

On this basis the cost of government has increased a great deal more in small towns than in the larger towns and cities. In a general way, expenditures per capita have tended to increase in inverse relation to the size of the town. This is shown graphically on Chart 2. Expenditures by the State and by counties have increased relatively less than for any other group.

CHART 2. Total Expenditures per Capita for All Purposes and for Local Purposes in Cities and Towns, 1910 and 1926, and the Percentage Increase.



Relative Importance of State and Local Expenses

The relative importance of the expenditures of the various groups is shown in Chart 3. Cities spent over three-fifths of the total of $356,971,000 in 1926. Towns of less than 5,000 population, which are largely rural, spent about one-tenth as much as cities.

Approximately one-sixth of the total expenditures were made by the State and counties for general puposes, while five-sixths were for local town or city purposes.

The Relation between Population and Expenditures Per Capita

Table 4 shows total expenditures per capita for towns and cities, grouped according to population, for the years 1907, 1912, 1917, 1922 and 1926. Substantial differences will be noted between groups each year. However, a change has taken place in the relation of population to expenditures per person. Until 1917, there was a fairly distinct tendency for expenditures per capita to bear a direct relationship to population, that is, for expenditures per capita in large

CHART 3. The Cost of Government, Showing the Percentage Distribution for the State, Counties, and Cities and Towns, 1926.

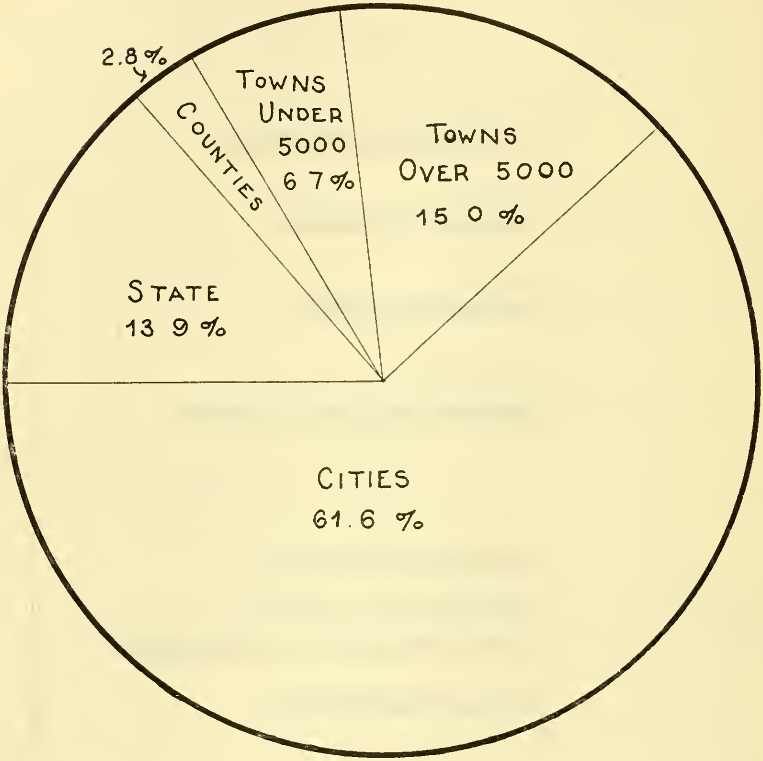


Table 4.—Total Expenditures Per Capita, by Size of City or Town, 1907, 1912, 1917, 1922 and 1926.

Size of City or Town	*1907*	*1912*	*1917*	*1922*	*1926*
Towns					
Under 1,000	$18.12	$20.76	$24.38	$50.86	$68.59
1,000-2,000	17.91	24.57	26.67	48.89	61.41
2,000-3,000	19.21	23.88	29.53	49.18	64.46
3,000-4,000	15.53	21.14	25.90	47.72	51.05
4,000-5,000	21.83	23.17	22,49	34.34	51.71
5,000-7,000	23.11	25.59	30.48	51.65	54.42
7,000-10,000	23.10	27.42	32.48	49.78	66.85
10,000-15,000	25.07	24.98	30.27	51.50	60.01
Over 15,000	69.78	38.69	36.32	60.53	73.50
Cities					
Under 25,000	25.91	31.38	32.62	50.91	60.07
25,000-50,000	27.33	30.48	36.36	55.69	62.67
50,000-75,000	29.58	31.20	39.57	58.16	81.14
75,000-100,000	26.92	32.63	30.22	45.14	50.04
100,000-150,000	23.88	28.22	37.87	63.39	67.98
150,000-200,000	......	. .	38.60	58.57	66.23
Over 200,000	52.43	52.37	55.47	81.65	101.57

towns to be larger than in small towns. The change is apparent in the figures for 1926. The cost per person is distinctly higher in towns of less than 3,000 than in towns of 3000 to 7000. Towns of more than 7000 show higher expenditures per capita than the midgroup, and the average is about the same as for small towns and for cities. The rise in expenditures per capita in towns under 1000 has been larger than for any other group, and present costs per person for this group are approximately the same as for the larger towns and cities. The reasons for this increase will be discussed in another section.

The Purpose of Public Expenditures

The increase in expenditures is more significant when analyzed according to the purpose for which the moneys have been spent. The increase in the costs of the several types of public service performed by State and local governments is shown in Chart 4 and Table 5. The percentage increase is shown in Table 6. It should be noted that the increases are in amounts expended for certain general purposes, and do not measure the increase in the cost of the same government service. It is obvious to any taxpayer that he is receiving more service than ever before. The figures given measure the increase in expenditures for this service.

Table 5.—Total Annual Expenditures in Massachusetts, by Purpose, 1910-1926.[1]

(Thousands of dollars)

Year	Interest and Debt	Highways and Waterways	Education	Charity, Health and Correction	Other General	Public Service Enterprises[2]	**Total**
1910	$24,595	$16,205	$24,258	$22,116	$26,027	$ 9,092	$122,293
1911	25,296	16,101	25,427	22,789	26,468	9,347	125,428
1912	25,056	19,205	27,382	25,560	29,483	11,080	138,766
1913	27,814	23,874	29,926	27,827	31,537	13,212	154,190
1914	28,986	26,769	31,601	29,531	32,240	13,626	162,753
1915	30,424	22,677	33,242	30,348	33,153	13,280	163,024
1916	31,819	23,918	33,690	30,816	33,332	12,489	166,064
1917	32,262	26,431	37,138	34,786	37,996	11,984	180,597
1918	34,901	24,764	37,767	36,789	41,237	11,526	186,984
1919	34,430	33,088	42,325	41,314	41,916	11,997	227,070
1920	37,066	40,453	58,964	47,506	53,229	15,506	252,724
1921	38,108	46,366	68,309	52,204	54,083	17,461	276,531
1922	40,668	44,459	75,115	52,533	55,474	17,168	285,417
1923	39,563	48,631	81,729	56,828	57,571	19,653	303,875
1924	41,445	57,867	87,455	62,045	61,509	21,286	331,607
1925	42,822	53,708	89,576	63,048	64,790	23,398	337,342
1926	46,265	60,238	93,621	65,550	65,956	25,341	356,971

[1] Expenditures for all purposes, including new construction.

[2] For cities and towns only.

From the tables it is apparent that the costs of highways and education have been and are still the two most important items in the public budget. They have become relatively more important, since expenditures for these purposes were almost four times as much in 1926 as in 1910, while expenditures for all other purposes were less than three times as much as in 1910. It is significant to note that the increase for meeting debt and interest charges has been less than for any other service. The change in the relative importance of the several groups of services is shown by comparing the importance of each in the public budget in 1910 and 1926. (Table 7). In 1910 one-third of all expenditures

CHART 4. Increase in the Cost of Various Groups of Public Services, 1910-1926. (Expressed in Percentages.)

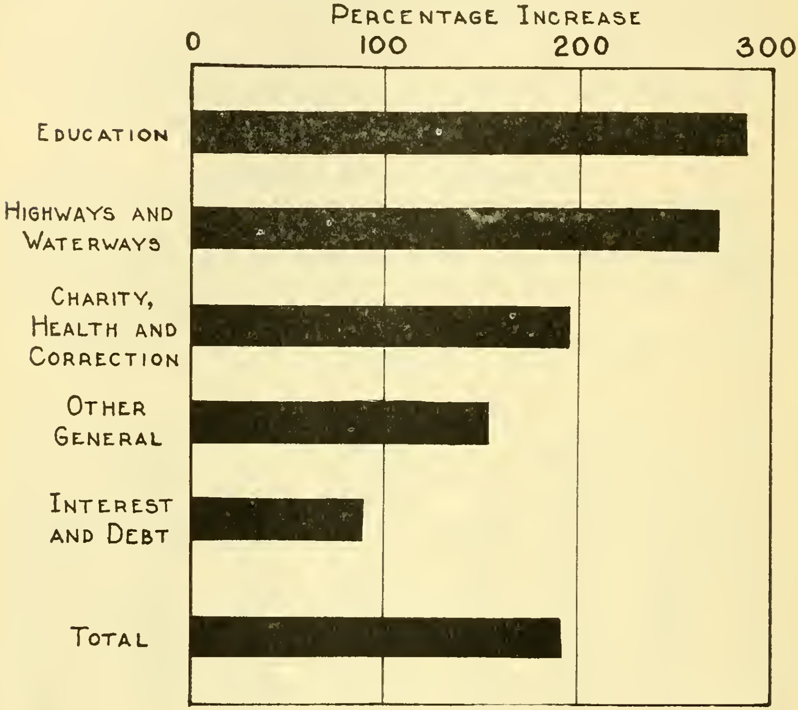


Table 6.—Increase in Cost of Certain Types of Government Service, 1910-1926.

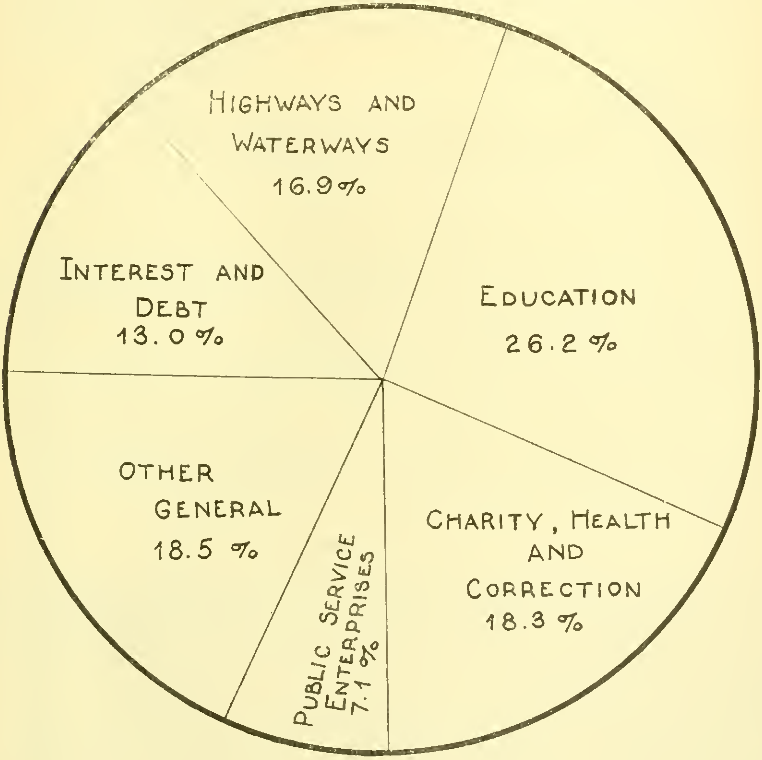
Type of Service	*Increase Per cent*
Interest and Debt	88.1
Highways and Waterways	271.7
Education	285.9
Charity, Health and Correction	196.4
Other General Expenses	153.4
Total	**191.9**

was for schools and highways; in 1926, 43 per cent were for these purposes. The increase for these two services has been accompanied by a decline in the charges for interest and debt from 20 per cent to less than 13 per cent. Other general expenses, including administration and fire and police protection, have declined nearly 3 per cent. Expenditures for charity, health and correction have retained their relative importance. The division of the public dollar according to purpose for which it is spent is shown in Chart 5.

Table 7.—Expenditures for Various Purposes, in Percentage of Total, 1910 and 1926.

	1910	*1926*
Interest and Debt	20.11	12.96
Highways and Waterways	13.25	16.87
Education	19.84	26.23
Charity, Health and Correction	18.08	18.36
Other General Expenses	21.28	18.48
Public Service Enterprises	7.44	7.10
Total	**100.00**	**100.00**

CHART 5. The Cost of Government, Showing the Percentage Distribution for Different Services, 1926.



Causes of the Increase in Public Expenditures

The increase in expenditures has been variously ascribed to the war, to high prices, or to municipal extravagance, and there is no single explanation. The reasons are manifold, and some apply to one group of cities and towns, some to another group.

The Effect of the War

The war has been responsible for the increase in expenditures in two ways. During the war, public expenditures for local purposes were kept to a minimum due to demands for economy. There were definite restrictions on municipal expenditures, particularly from bond issues. Consequently, State expenses alone show a significant increase during the war years, and the largest single war cost, the soldiers' bonus, was a post-war expense.

At the close of the war most cities and towns were several years behind in their building program. This deficiency had to be met together with current needs, at a level of prices at least 50 per cent higher than the pre-war level. Therefore the war was partly responsible for the increase in expenditures through the postponement of necessary building during the war, and indirectly through inflated prices.

The significance of post-war expenditures may be illustrated by comparing the average annual increase for pre-war and post-war periods.

	Average Annual Increase in Total Massachusetts Expenditures
1910-1918	$ 8,086,000
1919-1924	24,103,000

During the six years following the war, the average annual increase was approximately three times as much as before and during the war.

Increase in Population

The normal increase of population has been responsible for part of the increased cost of government. The population of Massachusetts increased 23 per cent between 1910 and 1925. Most of this increase has taken place in the cities and large towns. According to the population census of 1925, 110 of the smaller towns show a net loss in population since 1900. Obviously the increase in the cost of government in these towns must be accounted for on some other basis than increasing numbers of people. However, for the state as a unit, population has tended to increase at an annual rate of from 1 to 2 per cent. This has certainly been one cause of increasing public expenditures.

The Rise in Prices

The general rise in prices has been one of the most important causes of increased expenditures. During the five-year period, 1922-1926, wholesale prices averaged more than 50 per cent above 1913, according to the all-commodity index of the United States Bureau of Labor. The cost of government is determined largely by the price of materials and by the cost of labor services. Wages and salaries normally increase in about the same proportion as prices but slightly later, and it is to be expected that government costs should increase with prices. On this basis, government costs in 1926 would be 50 per cent higher than in 1910 for exactly the same amount of service; or, to state it another way, the tax dollar in 1926 would buy only two-thirds as much service as in 1910.

However, wages and salaries follow retail prices more closely than wholesale prices, and during the past five years retail prices have averaged from 60 to 70 per cent above pre-war figures, according to the Bureau of Labor. Wages of factory workers in New York have averaged more than double the pre-war scale, and this condition is considered typical of the general wage situation. Salaries of school teachers in Massachusetts have more than doubled, as will be shown later. Prices of building materials have also averaged higher than the general price level, or about 70 per cent above 1913 prices.

School and highway costs may be taken to illustrate the effect of the rise in prices. The cost of new construction is 70 per cent above pre-war figures for materials, while wages have doubled. Wages for personal services in maintaining schools and highways have also doubled. Therefore the costs for identical service would be from 70 to 100 per cent more than before the war, due solely to higher prices. The same conclusion is valid for all other public services with the exception of debt and interest charges, since most government service is personal service.

The increase in expenditures for schools and highways becomes less significant when considered in connection with higher prices. Most cities and towns attempted to catch up with their building program between 1920 and 1925, and at the same time to repair or rebuild thousands of miles of streets and highways, which was made necessary by the rapid increase in motor traffic. This construction at high prices has necessarily increased expenditures both from taxes and from bond issues.

Increase in Public Service

Another reason for the increase in public expenditures that is often overlooked by the taxpayers is the public demand for more and more service. There are two aspects of this increase in service; a demand for increasing the scope of present governmental activities, and an insistent demand that our State and local governments undertake new activities.

Highways and education illustrate the first point. People are demanding more and better streets and highways, boulevards, bridges, highway signs, more frequent highway repairs, street oiling or watering, snow removal, etc. The activities of the street and highway departments of cities and towns are constantly being increased.

In the same way, educational opportunities are being enlarged due to specific demands from the public. University and agricultural extension courses, night vocational schools, agricultural and other vocational courses in our high schools, all have been added to educational activities. At the same time there has been a demand for more courses and more subjects in our elementary schools, high schools, technical schools and colleges. More attention is being paid to health and recreation which has resulted in demands for gymnasiums and playgrounds, expensive to construct, and costly to maintain.

Other activities have been undertaken in connection with health, charity, and the care of the defective classes of society. The State has been especially active in the construction and maintenance of institutions for the care of the feeble-minded and insane. Physical examinations in the schools to correct physical defects, and supervised play in public playgrounds are new activities designed to improve public health. The state police is a new activity, brought into existence by the necessity for regulation of traffic on congested highways.

All of these new activities, together with the expansion of functions already being performed, add to the number of people on the public payroll and to public expenditures, all by and with the consent of taxpayers who believe that the increased expenditure is justified by the benefits received.

Municipal Extravagance

The statement is often made that municipal extravagance has been responsible for the increase in public expenditures. In some cases this has been true, if by extravagance is meant expenditures for things not essential to the public welfare. However, judgment as to what is extravagant may well be based on what the voters demand and are willing to pay for. A town or city may put more money into beautiful schools, libraries, parks, boulevards, or city buildings than appears to be justified by its size and rate of growth; but if such things are demanded by the public they are not extravagances of officials, at any rate.

One factor in the situation is that a great many voters are not property owners. In 1926 more than one-half of the individual taxpayers paid poll tax as the only direct tax, and apparently a substantial majority of the voters either did not own property, or were taxed merely on personal property. As long as this situation exists it is somewhat doubtful if the rate of increase in town and city expenditures can be confined to the requirements of a normal increase in population. In rural and other towns where most voters are property owners, it seems likely that as soon as taxes become burdensome the property owners will regulate expenditures more nearly in accordance with their ability to pay.

Table 8.—Index Numbers of Population, Commodity Prices, and Public Expenditures in Massachusetts, 1910-1926.

1910 = 100

Year	Population[1]	All Commodity Prices[2]	Total Expenditures		Expenditures per Capita	
			Actual	Deflated	Actual	Deflated
1910	100	100	100	100	100	100
1911	102	92	103	112	101	109
1912	104	98	113	115	109	111
1913	106	99	126	127	119	120
1914	108	97	133	137	123	127
1915	110	100	133	133	121	121
1916	111	125	136	109	122	99
1917	112	175	148	85	132	75
1918	113	192	153	80	135	71
1919	113	204	186	91	164	81
1920	114	223	207	93	181	81
1921	116	146	226	155	195	134
1922	118	147	233	159	197	135
1923	120	151	248	164	207	137
1924	121	147	271	184	224	152
1925	123	157	276	176	224	143
1926	125	151	292	193	234	155

[1] Census figures are available only at five-year intervals. Other years were estimated from the average change between census periods.

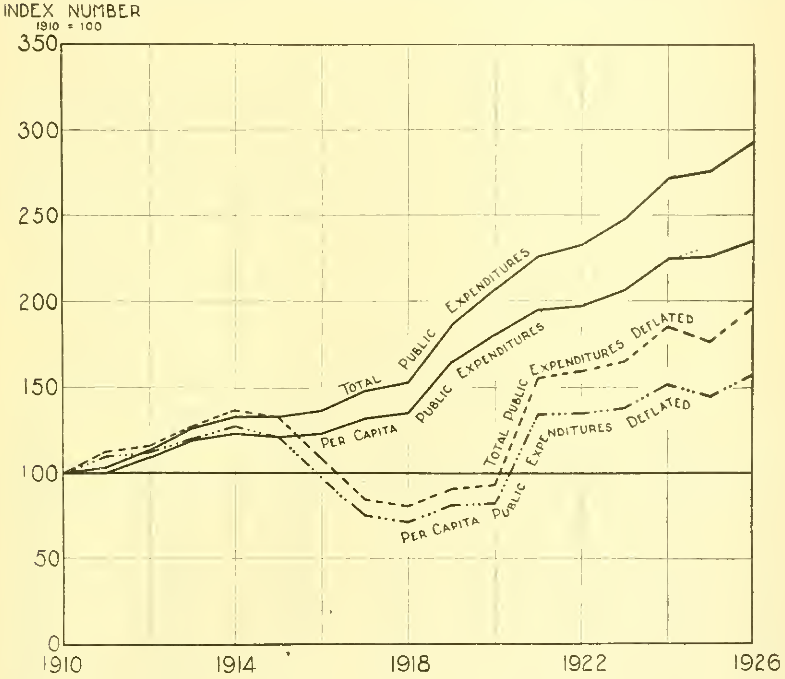
[2] United States Bureau of Labor index converted to a 1910 base.

The Significance of the Increase in Expenditures

While the increase in expenditures has been large, it has been shown that the growth of population together with the change in prices has exercised considerable influence on this increase. The effect of these factors is shown by index numbers in Table 8 and Chart 6, where total and per capita expenditures for each year have been reduced to percentages of expenditures in 1910. The index of total expenditures for 1926 is 292. Allowing for the increase in population, the per capita index in 1926 is 234.

CHART 6. Public Expenditures, Total and per Capita, Actual and Deflated by the Index of Wholesale Prices, 1910-1926.

(Expressed in Index Numbers with 1910 as the Base.)



These figures make no allowance for the increase in prices. If the Bureau of Labor Index of Wholesale Prices, converted to a 1910 base, is used as a measure of the changing value of the dollar, expenditures may be stated in terms of dollars with a constant value, their value in 1910. On this basis, total expenditures in 1926 were only 93 per cent higher than in 1910, and per capita expenditures gained only 55 per cent in the 17-year period.

From the chart it will be noted that during the war years the increase in expenditures did not equal the increase in prices, and for five years expenditures in deflated dollars were lower than in 1910, both in total and per capita. Tax payers were apparently getting the same service as before, but paying less for the service in terms of purchasing power.

The significance of the preceding discussion may be shown by reducing all expenditures to simple figures. In 1926 total expenditures were $2.92 for every dollar spent in 1910, and $2.34 per person for each dollar per person spent in 1910. In terms of purchasing power, allowing for higher prices, $1.93 was spent in 1926 for every dollar spent in 1910, and $1.55 per person was spent for every dollar per person in 1910.

If the cost of government service followed wholesale prices exactly, the figures would indicate that the amount of government service per person has increased 55 per cent since 1910. However, it was previously pointed out that government costs follow retail prices more closely than wholesale prices. If expenditures per person be deflated by the Federal Reserve Board Index[4] of the general price level, it appears that the net increase in amount of government service per person from 1910 to 1926 was 37 per cent. In the opinion of the authors, this is a fair estimate, and nearer the true situation than the 55 per cent shown above.

Interest and Debt

The payment of interest and annual payments on the principal of borrowed funds either to sinking funds or to redeem outstanding serial bonds are important fixed costs of government. Table 7 shows that one-eighth of the total annual expenditures is for these purposes, and that the percentage has been decreasing. In 1910, payments on account of debt were the largest group of expenses; while by 1926 the cost was less than any of the more important groups of services.

Table 9.—Expenditures for Interest and Debt, by Jurisdictions, 1910-1926.

(Thousands of dollars)

Year	Central State Gov't	Counties[1]	Towns Under 5,000	Towns Over 5,000	Cities	**Total**
1910	$ 2,442	$ 194	$ 648	$ 3,062	$ 18,249	**$ 24,595**
1911	2,486	180	698	3,244	18,688	**25,296**
1912	2,420	159	1,059	3,256	19,162	**26,056**
1913	2,971	172	1,131	3,456	20,084	**27,814**
1914	3,381	175	986	3,788	20,656	**28,986**
1915	3,353	175	1,077	3,425	22,394	**30,424**
1916	3,447	167	1,133	3,598	23,474	**31,819**
1917	3,973	187	1,181	3,713	23,208	**32,262**
1918	5,342	235	1,120	3,753	24,451	**34,901**
1919	4,614	187	1,158	3,601	24,870	**34,430**
1920	5,957	242	1,171	3,826	25,870	**37,066**
1921	5,045	250	1,373	4,120	27,320	**38,108**
1922	4,634	213	1,404	4,374	30,043	**40,668**
1923	3,810	196	1,556	4,562	29,439	**39,563**
1924	3,366	212	1,549	5,155	31,163	**41,445**
1925	3,263	319	1,715	5,750	31,775	**42,822**
1926	3,161	324	1,831	6,158	34,791	**46,265**

[1] Payments on debt not included.

Table 9 shows the cost of interest and debt for the various civil units. Cities pay three-fourths of the total, towns over 5,000 pay only one-eighth, and the State pays about one-twelfth. Counties and small towns spend less than

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[4] This index number includes retail prices, wages, and the cost of living.

5 per cent of the total. The importance of interest and debt payments in the budget for each group is shown in Table 11.

Until 1922 payments by the State government for interest and debt amounted to more than 10 per cent of State expenditures, but since that time the percentage has been dropping. The County figures on debt payments are not available except for the past few years.

Table 10.—Expenditures per Capita for Interest and Debt, by Size of City or Town, 1926.

Size of City or Town	Number of Cities or Towns	Interest	Debt	Total	*Per Cent of Total Expenditures*
Towns					
Under 1,000	83	$ .86	$1.03	$ 1.89	*2.75*
1,000-2,000	74	1.60	2.73	4.33	*7.02*
2,000-3.000	39	1.82	3.63	5.45	*8.45*
3,000-4,000	28	1.56	2.84	4.40	*8.62*
4,000-5,000	17	1.78	3.34	5.12	*9.90*
5,000-7,000	26	1.74	3.66	5.40	*9.90*
7,000-10,000	22	3.08	4.47	7.55	*11.30*
10,000-15,000	19	2.19	3.55	5.74	*9.53*
Over 15,000	12	4.31	5.99	10.30	*14.00*
Cities					
Under 25,000	13	2.74	5.71	8.45	*14.06*
25,000-50,000	11	3.60	6.34	9.94	*15.85*
50,000-75,000	5	4.62	7.43	12.05	*14.85*
75,000-100,000	2	2,85	3.79	6.64	*13.27*
100,000-150,000	6	4.78	7.47	12.25	*18.00*
150,000-200,000	1	3.49	6.10	9.59	*13.98*
Over 200,000	1	9.10	6.84	15,94	*15.68*

The proportion of the total municipal expenditures required for interest and debt payments tends to increase with the size of the town, but this does not seem to be true for the larger cities. (Table 10). In Table 11 it will be noted that interest and debt payments take twice as much of the budget in cities as in small towns. Considerable variation occurs between towns or cities in the same group. Thus, in cities of from 100,000 to 150,000 population, interest and debt payments per person ranged from $8.97 to $16.61 in 1926.

Many of the small towns have little or no debt, and the average is increased considerably by a few towns that are relatively wealthy and have borrowed much more than other towns of their size. Thus, 6 of the 44 towns of less than 500 population in 1926 paid 58 per cent of the total interest and debt of the group. For towns of less than 1,000 population, 68 per cent of interest and debt payments were made by 17 towns, in one of which per capita payments

Table 11.—Ratio of Payments for Interest and Debt to Total Expenditures, 1926. *(Percentages)*

Jurisdiction	*Interest*	*Debt*	**Total**
Central State Gov't.	2.7	3.7	**6.4**
Counties	3.3	—[1]	**3.3**
Towns under 5,000	2.7	4.9	**7.6**
Towns over 5,000	4.5	7.0	**11.5**
Cities	7.0	8.8	**15.8**

[1] Debt figures not available.

averaged $11.50. Similar variations occur in the other groups, and the principal significance of Table 11 is that it shows the average change in the relative importance of interest and debt with an increase in population.

Highways

The construction and maintenance of streets and highways takes about one-sixth of the total budget in Massachusetts. Over $59,000,000 was spent for highways in 1926, which is the last year for which complete figures are available. This figure was more than 270 per cent higher than in 1910. From 1910 to 1919 highway expenditures doubled, and they have almost doubled again since that time.

Tables 12 and 13 show the relative changes in highway expenditures by jurisdictions from 1910 to 1926.

Table 12.—Expenditures for Highways, by Jurisdictions, 1910-1926.[1]
(Thousands of dollars)

Year	Central State Gov't	Counties	Towns Under 5,000[2]	Towns Over 5,000[2]	Cities[2]	Total
1910	$ 2,008	$ 383	$ 1,373	$ 2,421	$ 9,600	$ 15,785
1911	2,114	369	1,338	2,518	9,050	15,389
1912	2,710	533	2,189	2,767	10,401	18,600
1913	3,388	601	2,437	2,865	11,979	21,270
1914	3,937	705	2,286	3,300	13,230	23,458
1915	2,910	681	2,568	3,306	12,127	21,592
1916	3,301	841	2,556	3,541	11,698	21,937
1917	4,828	899	2,594	2,760	12,889	24,970
1918	4,009	904	2,457	3,172	12,179	22,721
1919	3,787	929	3,453	4,344	17,550	30,063
1920	5,697	1,886	4,902	5,656	20,526	38,667
1921	7,564	4,759	4,559	6,394	21,758	45,034
1922	7,882	3,694	4,837	6,140	20,649	43,202
1923	9,252	3,095	5,643	6,715	22,885	47,590
1924	11,540	2,384	5,825	8,363	29,011	57,123
1925	10,962	2,704	6,524	8,124	24,955	53,269
1926	12,484	2,294	7,441	9,594	27,848	59,661

[1] Includes new construction.

[2] Payments for both maintenance and construction are shown in Table A 1.

State highway expenses have increased much more rapidly than municipal highway expenses due to the rapid development of the State highway system, and to the fact that cities and large towns had well developed street systems

Table 13.—Increase in Highway Expenditures, 1910-1926.

Jurisdiction	*Increase Per cent*
Central State Gov't.	521.7
Counties	499.0[1]
Towns under 5,000	441.9[2]
Towns over 5,000	296.3
Cities	190.1
Total	**278.0**

[1] This large increase is not significant, since county highway expenditures are only 5 per cent of all highway costs.

[2] 1910 base figures were not complete.

before the recent increase in automobile travel. The increase in county expenses is due in part to the building of several important bridges. Highway expenditures in towns have apparently increased much more rapidly than in cities.

Cities now pay approximately one-half of the total cost of highways, either for streets or for highways within their limits. The State pays approximately one-fifth, and the percentage has increased rapidly during the past few years. The distribution of highway expenses for selected years is shown in Table 14. The State, counties and small towns pay relatively more, while cities and large towns together pay only 62 per cent of the total instead of three-fourths as in 1910.

Table 14.—Distribution of Total Highway Expenditures for Selected Years.

(Percentages)

Year	Central State Gov't	Counties	Towns Under 5,000	Towns Over 5,000	Cities	All Groups
1910	12.72	2.42	8.70	15.34	60.82	100.00
1915	13.48	3.15	11.89	15.31	56.17	100.00
1920	14.73	4.88	12.68	14.63	53.08	100.00
1925	20.58	5.08	12.25	15.25	46.84	100.00
1926	20.92	3.85	12.47	16.08	46.68	100.00

With the exception of 1924 a larger part of public funds is now devoted to highway purposes than at any time since 1910. Table 15 illustrates the change in the relation of highway expenditures to total expenditures.

Table 15.—Relation of Highway Expenditures to Total Expenditures, by Jurisdictions, 1910-1926.

(Percentages)

Year	Central State Gov't	Counties	Towns Under 5,000	Towns Over 5,000	Cities	All Groups
1910	10.51	10.52	22.41	13.91	12.63	12.91
1915	10.64	17.00	25,29	15.65	12.08	13.24
1920	12.19	27.33	30.63	17.27	13.65	15.30
1925	22.85	26.69	28.83	16.26	12.08	15.79
1926	25.07	23.24	31.05	17.96	12.66	16.71

Highway costs take a larger share of public expenditures than in 1910 for each of the groups except cities, which remains about the same. In 1926, 16.7 cents out of every dollar spent was for highways compared with 12.9 cents in 1910. The change of 3.8 cents represents a 29 per cent increase in the relative importance of highways. One-fourth of the State expenditures is now devoted to highways, compared with only 10.5 per cent in 1910. The increase for counties has been about the same as for the State. While a larger share of municipal expenditures is required for highway purposes than formerly, the increase has not been as great in cities as in towns. More than 31 per cent of the budget of small towns is for highways, while cities spend slightly over 12 per cent. The importance of highways in the town budget tends to decrease as the town becomes larger. This is illustrated by Table 16. In the 83 towns of less than 1,000 population, highways take 49 per cent of the total expenditures and the per

Table 16.—Expenditures per Capita for Highways, by Size of City or Town, 1926.

Size of City or Town	Number of Cities or Towns	Maintenance	Construction	Total	*Per Cent of Total Expenditures*
Towns					
Under 1,000	83	$18.49	$13.11	$31.60	*49.00*
1,000-2,000	74	12.23	8.77	21.00	*34.20*
2,000-3,000	39	11.08	6.88	17.96	*27.89*
3,000-4,000	28	7.94	5.15	13.09	*25.60*
4,000-5,000	17	7.25	5.87	13.12	*25.40*
5,000-7,000	26	7.28	4.87	12.15	*22.30*
7,000-10,000	22	7.44	3.68	11.12	*16.65*
10,000-15,000	19	5.77	4.36	10.13	*16.88*
Over 15,000	12	6.91	6.05	12.96	*17.62*
Cities					
Under 25,000	13	5.59	2.96	8.55	*14.25*
25,000-50,000	11	4.15	4.63	8.78	*14.00*
50,000-75,000	5	5.33	4.00	9.33	*11.50*
75,000-100,000	2	3.45	2.33	5.78	*11.55*
100,000-150,000	6	4.45	5.11	9.56	*14.07*
150,000-200,000	1	5.31	3.20	8.51	*12.40*
Over 200,000	1	5.34	6.34	11.68	*11.50*

capita payments for highways are three times as large as the average for cities.

Comparatively large highway costs in rural towns are significant for two reasons. First, if the town spends the largest part of its income for highways other functions may suffer, which means that rural towns are unable to enjoy certain services available to larger towns and cities. In 1926, 51 per cent of the expenditures of the 44 towns of less than 500 population was for highways.

The rural towns have more miles of road per taxpayer than the more densely populated towns, and the assessed valuation per mile of road is lower. This means that with equal tax rates for highway purposes, the roads can not be kept in as good condition as in towns where the assessed valuation per mile of road is high. In respect to highways, small towns are therefore under a double disadvantage in that they spend proportionally more for roads than larger towns and receive less in service because of a lower expenditure per mile which may leave roads in poorer condition.

The Significance of High Costs for Highways

Large expenditures for highways have been justified by the increased ease of transportation. Massachusetts has a high percentage of surfaced roads, which has materially reduced cost of intra-state transportation. The network of State highways, largely constructed during the past ten years, has opened relatively isolated farming districts and has expanded the farmers' market area in all directions. Fruit and vegetable growers now haul their products from the Connecticut Valley to Boston, a distance of 100 miles. Farmers in the hill towns of the western part of the state now sell fluid milk, collected at the door, instead of cream and butter, thereby increasing their farm income. The area supplying perishable food stuffs to our cities has been much increased through motor transportation and good roads. Roadside selling by farmers has been made possible by the expansion of the highway system.

Increasing expenditures for better roads have brought substantial returns.

Automobile traffic has grown to such an extent that it is estimated that automobiles and motor trucks pay taxes and fees equal to nearly 30 per cent of the annual expenditures for highway purposes[5]. In addition, a portion of the original cost of new streets and highways has been paid by taxes on the increase in the assessed valuation of real estate, due to such improvements. This increase has been justified by the greater earning power of farm property resulting from improved highways. State and county highways through farming districts have cost the local towns relatively little, and the increase in property values has added to the assessed valuations giving more taxes with which to improve town roads.

In addition to the above advantages accruing to the local towns, State financial aid for highway purposes partly offsets the disadvantage of such towns previously mentioned. Most rural towns receive considerably more highway service than they pay for, either as State highways or as direct financial aid from the State for local highway purposes.

State Aid for Highways

Small towns have been unable to construct and maintain the highways made necessary by the increase in automobile traffic. The State has therefore found it necessary to assist them in two ways; first, by the construction and maintenance of State highways, to the cost of which towns may or may not contribute; and second, by grants of money to towns for highway purposes or through the donation of services by the State highway division. State aid proper falls under the second classification.

Table 17.—Minimum Town Appropriations Necessary to Receive State Highway Aid.

Road Mileage Ratio	*Town Appropriation per Mile*	*Road Mileage Ratio*	*Town Appropriation per Mile*
Less than $1.40	$15.00	$3.50-5.50	$ 75.00
1.40-2.00	25.00	5.50-7.00	100.00
2.00-2.80	40.00	7.00-9.00	125.00
2.80-3.50	50.00	9.00-12.00	150.00

The division of highways of the Department of Public Works, is authorized by law (Small Towns Act, 1918) to spend up to $150 per mile for the repair and improvement of roads in towns in which the property valuation is less than $4,000,000, and in which the road mileage ratio is less than $12. The road mileage ratio is the proportionate amount of each million dollars of State taxes paid by the town divided by the number of miles of public highway within the town. In order to secure this aid, towns must make minimum appropriations as shown in Table 17. Both town and State appropriations under this act must be expended under the direction of the State division of highways upon such roads in each town as are jointly agreed upon by the division and the selectmen

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[5] Estimates based on receipts previous to the gasoline tax and automobile excise tax established in 1929.

State registration, licenses, fines and fees	$12,500,000
Property taxes paid to cities and towns	5,000,000
Total	$17,500,000

of the town. The act limits expenditures to roads in thinly settled areas and specifies that none shall be made in districts where houses or other structures devoted to business are situated at intervals averaging less than 200 feet for the distance of a quarter of a mile. The State paid out $807,000 under this act in 1926.

The division of highways is also authorized by law to spend 5 per cent of each annual appropriation for the construction of State highways in the building and repair of highways in towns of less than $1,000,000 assessed valuation. A second 5 per cent may be devoted to this purpose provided the towns appropriate an amount equal to that allotted by the division. Five per cent may also be used in towns with an assessed valuation of more than $1,000,000 provided the towns appropriate an amount equal to that allotted by the division, over and above the average annual highway appropriation for the five preceding years.

Under the above act (General Laws, Chapter 81, Section 23) the amount spent in towns with a valuation of less than $1,000,000 making no additional appropriations is limited to 40 per cent of the five-year average town appropriation for highways, except that a minimum of $400 is allowed to towns in which the annual highway appropriation has averaged less than $1,000 for five years.

In addition to the provisions above, the division of highways is authorized to spend 20 per cent of the net amount received from motor vehicle fees and fines in the improvement of town and county roads not State highways. At the present time this would amount to more than $2,500,000. In 1926, $1,590,000 was used by the State in the "construction of town and county ways."

Education

Total expenditures for educational purposes by all public agencies amounted to $93,600,000 in 1926. Of this amount, $3,675,000 was for libraries and $89,925,000 was for schools and other educational purposes. Education is therefore

Table 18.—Expenditures for Education, by Jurisdictions, 1910-1926.[1]
(Thousands of dollars)

Year	Central State Gov't	Counties	Towns Under 5,000[2]	Towns Over 5,000[2]	Cities[2]	Total
1910	$1,789	$ 95	$ 2,051	$ 4,350	$ 15,973	$ 24,258
1911	1,872	95	2,010	4,338	17,112	25,427
1912	2,028	102	3,073	4,548	17,631	27,382
1913	2,309	210	3,311	5,005	19,091	29,926
1914	2,346	194	2,791	5,574	20,696	31,601
1915	3,071	197	3,190	5,627	21,157	33,242
1916	2,753	215	3,304	5,925	21,493	33,690
1917	3,099	331	3,529	6,528	23,651	37,138
1918	3,276	410	3,445	6,286	24,350	37,767
1919	3,730	456	4,192	7,253	26,694	42,325
1920	4,828	418	5,414	10,399	37,875	58,964
1921	5,332	577	6,419	11,754	44,227	68,309
1922	6,342	582	7,232	13,251	47,708	75,115
1923	6,557	741	7,569	14,267	52,595	81,729
1924	6,448	631	7,930	17,431	55,015	87,455
1925	6,914	644	8,261	16,701	57,056	89,576
1926	7,097	653	8,365	16,689	60,817	93,621

[1] Includes new construction.

[2] Payments for both maintenance and construction are shown in Table A 1.

the most important public activity in Massachusetts, receiving about one-fourth of the public expenditures. Chart 7 shows the amount spent for education annually from 1910 to 1926. The amount spent for education by each civil group is shown in Table 18.

Expenditures for education have increased considerably for all groups, and the total amount in 1926 was 286 per cent more than in 1910.

CHART 7. The Increase in Expenditures for Education, Total and per Capita, 1910-1926. (Expressed in Index Numbers with 1910 as the Base.)

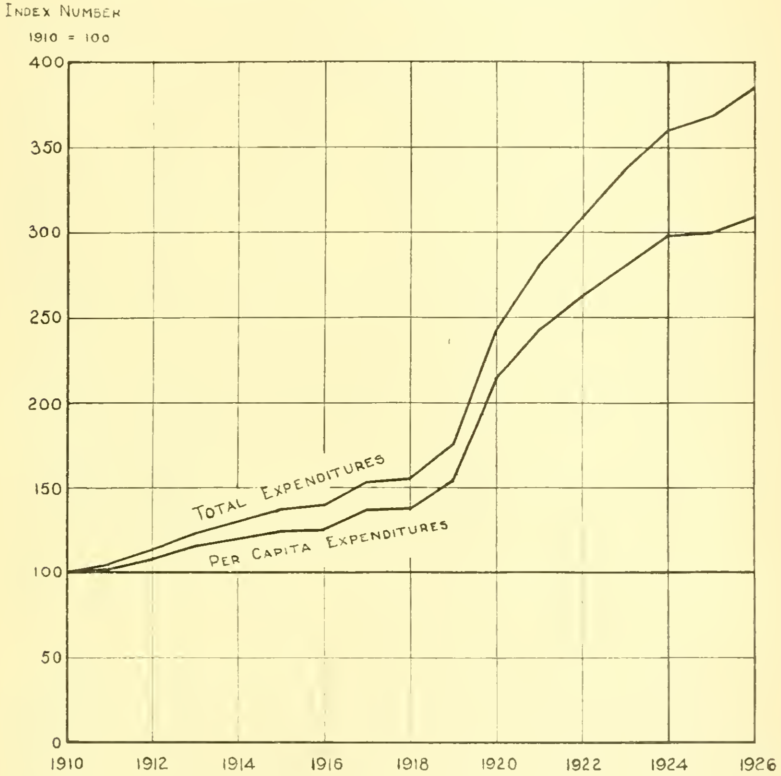

Table 19.—Increase in Expenditures for Education, 1910-1926.

Jurisdiction	*Increase Per cent*
Central State Gov't.	296.7
Counties	587.4[1]
Towns under 5,000	307.9[2]
Towns over 5,000	283.7
Cities	280.7
Total	**285.9**

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[1] This increase, while large, is insignificant, due to the fact that county expenditures for education are only .7 per cent of the total.

[2] 1910 base figures were incomplete.

From Table 19 it is apparent that educational expenditures in the towns have increased much more rapidly than in cities. County expenditures for education were insignificant prior to the establishment of county agricultural schools, and the increase has been due principally to the development of these schools.

Cities pay 65 per cent of the total cost of education, the large towns 18 per cent, and towns under 5,000, 9 per cent. County expenditures are less than 1 per cent. The relative proportions used by the State, and by counties, cities and towns have changed very little since 1910.

Table 20.—Relation of Expenditures for Education to Total Expenditures, by Jurisdictions, 1910-1926.
(Percentages)

Year	Central State Gov't	Counties	Towns Under 5,000	Towns Over 5,000	Cities	**All Groups**
1910	9.37	2.61	33.47	24.99	21.01	**18.08**
1915	11.23	4.92	21.42	26.63	21.07	**20.39**
1920	10.33	6.49	33.83	31.75	25.19	**23.33**
1925	14.41	6.36	36.50	33.42	27.61	**26.55**
1916	14.25	6.62	34.90	31.24	27.65	**26.23**

Education tends to take a larger share of public expenditures each year. From 1910 to 1926 the percentage of total expenditures for educational purposes increased from 18 per cent to 26 per cent. The relative proportion of total expenditures going to education varies from 6 per cent in the counties to 35 per cent in the small towns. The ratio of expenses for education to total expenditures in cities and towns tends to vary inversely with the population, the small towns expending proportionally from one-third to one-half more than the larger towns and cities. (Table 20).

In 1926, 35 per cent of the budget of towns under 5,000 population was for education, compared with 28 per cent for cities. The difference of 7 per cent

Table 21.—Expenditures per Capita for Schools, by Size of City or Town, 1926.

Size of City or Town	Number of Cities or Towns	Maintenance	Outlays	Total	*Per cent of Total Expenditures*
Towns					
Under 1000	83	$22.32	$1.01	$23.33	*34.03*
1000-2000	74	18.23	1.41	19.64	*31.95*
2000-3000	39	16.77	3.90	20.67	*32.00*
3000-4000	28	15.24	2.15	17.39	*34.10*
4000-5000	17	14.51	5.57	20.08	*38.80*
5000-7000	26	15.47	2.94	18.41	*33.80*
7000-10000	22	15.83	4.59	20.42	*30.50*
10000-15000	19	14.55	4.78	19.33	*32.20*
Over 15000	12	15.82	3.19	19.01	*25.80*
Cities					
Under 25,000	13	13.86	3.46	17.32	*28.85*
25,000-50,000	11	14.09	3.79	17.88	*28.50*
50,000-75,000	5	15.90	5.69	21.59	*26.60*
75,000-100,000	2	12.83	1.36	14.19	*28.35*
100,000-150,000	6	15.21	2.45	17.66	*26.00*
150,000-200,000	1	17.15	3.34	20.49	*29.88*
Over 200,000	1	19.13	5.89	25.02	*24.65*

means that small towns spent proportionally 25 per cent more than cities. A more detailed statement of the differences between towns is contained in Table 21.

Educational Activities of the State Government

State expenditures for education are intended to meet needs not adequately covered by local disbursements. In 1926, the State spent $6,759,000 for education. This amount included $350,000 contributed by cities and by the Federal Government.

The training of teachers for elementary schools is usually conceded to be a proper function of the State, and nearly one-fourth of the State expenditures for education in 1926 was devoted to the support of the ten normal schools.

The costs of some of the more important State educational institutions and activities in 1926 were as follows:[6]

Normal Schools	$1,628,000	
Vocational Education	1,544,000	(including Federal grants)
Massachusetts Agricultural College	916,000	(including Federal grants)
Education of the Deaf and Blind	758,000	
Teachers' Retirement	529,000	(including pensions and cost of retirement adminstration)
Aid to Shall Towns	452,000	
University Extension	354,000	
Textile Schools	288,000	
Nautical School	94,000	

It will be noted that most of the above activities are of a vocational nature. Approximately five-sixths of the State expenditures for education are for vocational purposes.

County Expenses for Education

Counties spent $653,000 for education in 1926, of which $464,000 was for agricultural high schools and county agricultural extension teaching. The remainder was for county training schools for habitual truants and other school offenders. These two activities are the distinct functions of the county, and while they are important from the standpoint of results, the cost is only .7 per cent of the total for education.

Causes of the Increase in Town and City School Expenses[7]

Increase in Number of Pupils

The increase in number of pupils has been important in increasing school expenses. Schools are subject to the law of decreasing costs, in that with a given school plant, an increase in the number of pupils lowers the cost per pupil up to the point where the existing buildings and equipment become inadequate. After this point is reached, the new construction necessary to avoid crowding increases the cost per pupil both because of the building cost and the increased teaching staff. Apparently school buildings in many cities and towns reached the limit of their capacity during the war years when building was curtailed. The increase in number of pupils is shown in Table 22. The total membership of all public day schools increased 39 per cent, while the enrollment in high schools doubled.

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[6] These totals represent gross expenditures and make no allowances for earnings and other receipts of the several divisions.

[7] All figures in this section have been taken from reports of the State Department of Education, unless otherwise indicated.

Table 22.—Average Membership in Massachusetts Public Schools, 1910-1925.

Year	**All Public Day Schools**	*High Schools*	*Elementary Schools*
1910	**479,069**	59,068	420,001
1915	**541,088**	76,396	465,692
1920	**563,693**	88,628	475,065
1925	**666,817**	118,125	548,692

Growth of High Schools

Increased high school attendance has made necessary more buildings and teachers. In 1920, high schools took 19.5 per cent of the total expenditures for school maintenance; in 1925 this percentage was 25.5. The increase in high school enrollment has increased school expenses more than would a similar growth in grade schools. Salaries in high schools are higher than in grade schools, classes are smaller, and the building and equipment requirements per pupil are greater.

New Buildings and Equipment

The value of school property increased from $119,000,000 in 1920 to nearly $184,000,000 in 1925, or 54 per cent. During the same period the value of school buildings increased from $93,000,000 to $150,000,000, or 61 per cent. High school building values practically doubled, while elementary schools increased only 43 per cent. A comparison of these figures with the increase in school enrollment indicates the probability that on the average, present building facilities are fairly adequate.

Increase in Teachers' Salaries.

The average salary paid Massachusetts school teachers has more than doubled during the past ten years, which is about the same rate of increase as in other occupations. Salaries in towns under 5,000 population have increased much more than in cities, but salaries in cities are still 50 per cent higher than

Table 23.—Average Salaries of Teachers.

Group	*1915*	*1920*	*1925*	*Increase 1915-1925 Per cent*
Cities	$983	$1,506	$1,875	*90.7*
Towns over 5,000				
with high schools	698	1,472	1,548	*121.7*
Towns under 5,000:				
with high schools	486	1,243	1,307	*158.6*
without high schools		1,069	1,142	
State average	**836**	**1,658**	**1,729**	**106.7**

in small towns. For the state as a whole, salaries doubled between 1915 and 1920; the increase since that time has been small. (Table 23).

The Educational Handicap of Small Towns

Small towns spend more per person, more per pupil, and more per $1000 of assessed valuation than larger towns and cities. At the same time they have more poor buildings, less equipment per pupil, and a larger percentage of inexperienced teachers.

Table 24.—Investment per Pupil in School Property and in Buildings, 1920 and 1925

Group	1920		1925	
	Total Property	Buildings	Total Property	Buildings
Cities	$222	$171	$278	$223
Towns over 5,000 with high schools	216	174	325	273
Towns under 5,000 with high schools	148	123	205	174
Towns under 5,000 without high schools	136	116	154	133

Differences in School Buildings and Equipment

The relative difference in school property between towns and cities of different sizes is shown by Table 24. It is apparent that, in a general way, the value of school property per pupil varies with population. The towns of more than 5,000 population had a higher value of property per pupil in 1925, due to new building since 1921. (Table 25). In 1920 the expenditures per pupil for construction and equipment were about the same for cities and large towns, but from 1921 until 1925 the per pupil outlays were much larger for the towns.

Table 25.—Assessed Valuation and Expenditures per Pupil, 1915 and 1925.

Group	Assessed Valuation	Expenditures	Source of Funds			*Per cent of Total School Expenditures from State Aid*
			Local Taxes	State Aid	Other	
		1915				
Cities	$9,303	$41.88	$41.56	$ .02	$ .30	*.047*
Towns over 5,000 with high schools	6,772	35.71	34.71	.11	.89	*.031*
All towns under 5,000	7,041	39.92	33.41	5.81	.70	*14.500*
State Average	**8,506**	**40.41**	**39.13**	**.804**	**.48**	*1.980*
		1925				
Cities	10,436	88.43	80.78	6.55	1.10	*7.4*
Towns with 5,000 with high schools	7,706	80.19	70.75	7.11	2.33	*8.8*
Towns under 5,000 with high schools	7,330	85.39	68.78	12.97	3.64	*15.2*
Towns under 5,000 without high schools	6,759	89.03	62.85	23.87	2.31	*26.8*
State Average	**8,801**	**86.54**	**77.09**	**7.84**	**1.95**	*9.0*

Extensive school construction for the state as a whole began in 1922 and 1923 and has been increasing each year.

The small increase in value of school property in the rural towns is accounted for partly by the closing of small schools and partly by the shifting of five towns to Group 3 through the construction of new high schools.

One-Room Schools

There were 657 one-room school buildings in use in 1925, or 130 less than in 1920. Nearly three-fourths of these were in towns of less than 5,000 population, but the number in use in this group has decreased 19 per cent since 1920. The consolidation of schools has in many cases reduced the number of teachers, with a consequent lower cost per pupil.

Table 26.—Training of Teachers in Public Elementary Schools, 1922 and 1924

Group	College or Normal School Graduates *Per cent*		Secondary School with one or more years' experience *Per cent*		Secondary School only *Per cent*		Not a Graduate of a Secondary School *Per cent*	
	1922	*1924*	*1922*	*1924*	*1922*	*1924*	*1922*	*1924*
Cities	88.5	89.0	6.3	6.6	4.6	3.9	.6	.5
Towns over 5,000 with high schools	80.4	81.2	10.3	10.2	8.7	7.8	.6	.8
Towns under 5,000 with high schools	67.8	66.7	12.1	15.2	18.9	17.1	1.2	1.0
Towns under 5,000 without high schools	49.6	58.1	14.2	14.5	32.4	25.4	3.8	2.0

Training of Teachers

Small towns of necessity employ many teachers with inadequate training. (Table 26). In 1924 only 58 per cent of the teachers in the small towns were graduates of normal schools or colleges, while one-fourth had no training above the high school and no teaching experience. In towns of less than 1,000 population, of which there were 70 reporting, 32.5 per cent of the teachers were graduates of normal schools and colleges, while 47.5 per cent had no training or experience beyond the high school.

Table 27.—Number of Pupils per Full-time Teacher, 1925.

Group	*Elementary Schools*	*High Schools*	**Average**
Cities	30.5	24.5	**29.2**
Towns over 5,000 with high schools	30.3	21.8	**28.2**
Towns under 5,000 with high schools	30.2	17.1	**26.5**
Towns under 5,000 without high schools	26.3	....	**26.3**
Towns under 1,000 without high schools	19.7	....	**19.7**
State average	**30.3**	**23.1**	**28.7**

Table 28.—Expenditures per Capita for Schools and Libraries, by Size of City or Town, 1912, 1917, 1922 and 1926.

Size of City or Town	1912		1917		1922		1926	
	Amount	*Per Cent of Total Expenditures*	Amount	*Per Cent of Total Expenditures*	Amount	*Per Cent of Total Expenditures*	Amount	*Per Cent of Total Expenditures*
Towns								
Under 1000	$7.93	*38.2*	$9.96	*40.9*	$21.37	*42.8*	$24.10	*35.1*
1,000-2,000	7.80	*31.8*	9.07	*34.0*	18.34	*37.5*	20.44	*33.3*
2,000-3,000	6.73	*28.2*	8.80	*29.8*	18.40	*37.4*	21.45	*33.3*
3,000-4,000	7.30	*34.5*	8.46	*32.7*	17.94	*37.6*	18.01	*35.3*
4,000-5,000	7.25	*31.3*	7.85	*34.9*	14.28	*41.6*	20.55	*39.8*
5,000-7,000	7.68	*30.0*	9.05	*29.7*	17.66	*34.2*	18.97	*34.8*
7,000-10,000	7.27	*26.5*	10.19	*31.4*	16.40	*32.9*	21.18	*31.7*
10,000-15,000	6.03	*24.1*	9.12	*30.1*	18.44	*35.8*	20.20	*33.7*
Over 15,000	7.93	*20.5*	9.43	*26.0*	20.98	*34.7*	19.07	*25.9*
Cities								
Under 25,000	7.42	*23.6*	7.58	*23.2*	15.31	*30.1*	18.10	*30.1*
25,000-50,000	7.29	*23.9*	9.11	*25.1*	16.98	*30.5*	18.50	*27.9*
50,000-75,000	6.52	*20.9*	9.30	*23.5*	13.95	*24.0*	22.44	*27.7*
75,000-100,000	7.03	*21.5*	7.43	*24.6*	14.25	*31.6*	15.27	*30.5*
100,000-150,000	5.98	*21.2*	8.46	*22.3*	17.67	*27.9*	18.45	*27.2*
150,000-200,000			9.30	*24.1*	17.44	*29.8*	21.27	*31.0*
Over 200,000	9.59	*18.3*	10.53	*19.0*	19.91	*24.4*	25.30	*24.9*

Efficient use of Teachers

It is impossible for small towns to use teachers as efficiently as large towns due to the small enrollment in many schools. Table 27 shows differences in number of pupils per teacher in cities and towns of different sizes.

Seventy towns of less than 1,000 population averaged less than 20 pupils per teacher, or only about two-thirds as many as the state average.

Cost per Person

Table 28 shows the per capita payments for school maintenance and for outlays, including new buildings and equipment, by size of town, for 1926. Towns of less than 1,000 population pay considerably more per capita for school maintenance than other groups.

Cost per Pupil

The cost per pupil is a better method of measuring the cost of education than the cost per capita. Table 25 shows the cost per pupil and the sources of funds. It will be noted that the total expenditure per pupil is fairly uniform for all groups, due to State Aid, the small towns receiving from the State over 26 per cent of the amount spent for schools.

The average cost per pupil for small towns is affected considerably by the large number of towns included in the group. If the towns under 1,000 population are considered separately, the results for 1925 are as follows:

Assessed valuation per pupil	$6,854.00
Expenditure per pupil	107.34
Expenditure per pupil from local taxes	57.16
Expenditure per pupil from State aid	50.18
Tax for education per $1,000 valuation	8.34
Percentage of expenditure per pupil received from State aid	46.7

The cost per pupil in this group is 21 per cent higher than the average for towns of less than 5,000 without high schools, and 24 per cent above the average for the state.

It is also important to note that in a general way expenditures from local taxes vary directly with the size of town, and while the small towns spend more per pupil, the amount from local taxes is not as great as in the larger towns.

Table 29.—Relation of School Funds from Local Taxes and from State Aid to Assessed Valuation, 1925.

(Expressed in dollars per $1000 valuation)

	Actual Tax for School Support	*Tax Required if Schools were Supported entirely by Local Taxes*	*Amount Received as State Aid*
Cities	$7.74	$ 8.47	$0.73
Towns over 5,000 with high schools	9.18	10.40	1.22
Towns under 5,000 with high schools	9.38	11.65	2.27
Towns under 5,000 without high schools	9.30	13.17	3.87
Towns under 1,000	8.34	15.65	7.31

The Relation between Cost per Pupil and Ability to Pay

One measure of the ability of a town to pay for schools is the assessed valuation per pupil. According to Table 25 the assessed valuation per pupil in towns of less than 5,000 population not maintaining high schools is only 64 per cent of the city valuation in 1925; the amount per pupil raised by local taxation in small towns was 78 per cent of the amount raised in cities. Therefore, on the basis of ability to pay, the towns spent relatively more than the cities. This is shown in Table 29, where the tax per $1000 valuation for school support in 1925 was 20 per cent larger in the small towns than in cities. However, the towns of less than 1000 population receive more in State aid, and the local tax per $1000 valuation was only $8.34 for school support. If total school expenditures were met locally it would require a tax of $15.65, or more than one-half of the total taxes in most towns. State aid reduces local school taxes by nearly one-half in the 70 towns of less than 1000 population.

State Aid for Schools

It has been pointed out that State aid to small towns makes it possible for them to spend more per pupil than larger cities and towns, thereby more nearly equalizing educational opportunities between towns. The larger part of State Aid for education is provided for under the General School Fund Law passed in 1919 (General Laws, Chapter 70, Sections 4, 5, 10-17). Funds are distributed from two parts of the General School Fund: Part I, a portion of the income tax; and Part II, the income from the Massachusetts School Fund.

Distributions are made from Part I on two bases: (1) the salary, training and experience of teachers; and (2) the assessed valuation per pupil according to the last state valuation.[8] All distributions under Part I are used to increase teachers' salaries. Reimbursement to towns is based on salary, training and experience as follows:

Education and Experience	*Salary*	*Reimbursement per Teacher*
College or normal school graduate with two full years' experience	$950 or more	$200
College or normal school graduate with one year's experience, or one year normal school and three years' experience	850 or more	150
No requirement	750 or more	100

A second distribution, based on the relation between the number of pupils and the proportionate amount of State tax paid by the town, is made as follows:

Pupil Tax Ratio[1]	*Reimbursement per Teacher*
Less than $.60	$250
.60 - .65	200
.65 - .70	150
.70 - .80	125
.80 - .85	100
.85 - .95	50

[1] This basis of reimbursement was adopted in 1926.

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[8] The state valuation attempts to equalize differences in assessment practice between towns to give valuation figures that are more nearly comparable between towns than the valuations of local boards of assessors.

The proportion of every million dollars of State taxes paid by the town is divided by the net average membership of public day schools to give the quotient in Column 1. Certain other provisions have been made for the benefit of small towns.

The first distribution is intended to encourage the employment of better trained teachers at fair salaries. The second distribution is intended partially to equalize ability to pay between towns of high and low valuations. In recent years more than $4,000,000 of the income tax was distributed under the educational provisions of the General School Fund Law. About one-eighth of this was distributed to towns of less than 5,000 population.

Distributions under Part II of the General School Fund Law are made from the income of the Massachusetts School Fund, a permanent fund of over $5,000,000 supplemented by certain income tax payments. In 1925 total payments amounted to $405,000, of which $189,000 were received from the Income Tax Fund of 1924. Distributions are made to towns with an assessed state valuation of less than $3,000,000 in which the local tax for school support is more than $5.00 per $1000 valuation. The method of distribution is complicated, but the amount received by each town varies directly with the local school tax and inversely with the valuation. The total amount is distributed to towns of less than 5,000 population, about one-half going to the group not maintaining high schools.

Other Aid

Where two or more towns whose joint valuation is less than $3,500,000 form a superintendency union and hire a school superintendent, the State may and does pay two-thirds of the salary and traveling expenses of the superintendent up to two-thirds of $2,500 for salary and $400 for traveling expenses. Over $82,000 was paid under this provision in 1925. The State also pays a part of the tuition and transportation costs of high school pupils in towns of less than 500 families not maintaining high schools, if the valuation per pupil is less than the state average. Reimbursement for tuition is as follows:

Assessed Valuation of Town	*Tuition Reimbursement*
$500,000 or less	Full
$500,000 - 1,000,000	Three-fourths
Over $1,000,000	One-half

Reimbursement for transportation up to 40 cents per day is made as follows:

Preceding 3-year average Expenditure for Schools Per $1000 Valuation from Local Taxation	*Transportation Reimbursement*
$4 - 5	One-half
5 - 6	Three-fourths
Over 6	Full

During the year ending November 30, 1925, small towns received $165,000 as reimbursement for high school tuition, and $128,000 for high school transportation.

The State also aids in the support of high schools in towns of less than 500 families, provided the valuation per pupil does not exceed the state average, and the high school is approved by the State Department of Education. Reimbursement of $250 is made for each full-time teacher, and a proportionate amount for part-time teachers. The maximum amount allowed to any town is $1250.

With the aid of the Federal Smith-Hughes Fund, the State supports continuation and vocational schools to the extent of reimbursing cities and towns for one-half the net cost of maintenance, except that agricultural departments of high schools are reimbursed for two-thirds of the salary of instructors. In 1925, State reimbursement to cities and towns for vocational education amounted to $1,218,000from State funds and $179,000 from Federal funds. Cities and towns maintaining English-speaking classes for adults were also reimbursed one-half of the cost of maintenance, or $167,000.

Libraries

The State board of library commissioners is authorized to spend $10,000 annually in aiding free public libraries in towns with a valuation of less than $1,000,000. They may also purchase books to the value of $100 for distribution to towns having no library, if the town fulfills certain requirements in appointing a library committee and in providing for the care and distribution of the books.

Table 30.—Expenditures for Charity, Health, and Correction, by Jurisdictions, 1910-1926.[1]
(Thousands of dollars)

Year	Central State Gov't	Counties	Towns Under 5,000[2]	Towns Over 5,000[2]	Cities[2]	Total
1910	$ 7,329	$ 574	$ 537	$ 2,088	$ 11,588	$ 22,116
1911	7,714	586	535	2,150	11.804	22,789
1912	8,225	608	812	2,172	13,743	25,560
1913	8,839	598	934	2,426	15,030	27,827
1914	9,820	648	968	2,655	15,440	29,531
1915	9,418	673	895	2,743	16,519	30,248
1916	10,139	689	911	2,706	16,371	30,816
1917	11,618	992	925	2,769	18,482	34,786
1918	13,124	1,470	926	2.680	18,589	36,789
1919	13,732	1,155	1,294	3.458	21,675	41,314
1920	15.430	1,211	1,332	3.908	25,625	47,506
1921	15,879	1,305	1,517	4.711	28,792	52,204
1922	16,212	1,885	1,468	4,435	29,333	52,533
1923	16.862	1,128	1,537	5.193	32,108	56,828
1924	16,745	1,063	1,893	6,031	36,313	62,045
1925	16,979	1.341	1,712	5,709	37,307	63,048
1926	17,507	1,582	1,791	6.766	37,904	65,550

[1] Includes new construction.

[2] Payments for both maintenance and construction are shown in Table A 1.

Charity, Health and Correction[9]

Massachusetts spent $65,500,000 for these activities in 1926, and the amount has increased in about the same proportion as total expenditures since 1910. Table 30 shows the amount spent each year.

Cities now pay 57.9 per cent of the total cost of such activities, as compared

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[9] City expenditures for prisons have not been included under correction, since under the state classification of accounts, these are charged to protection of persons and property.

Table 31.—Expenditures for Charity, Health and Correction, 1926.
(Amounts in thousands of dollars)

	Amount	*Per Cent of Total Expenditures*	Amount	*Per Cent of Total Expenditures*	Amount	*Per Cent of Total Expenditures*
	Central State Gov't		Counties		Towns under 5,000	
Charity	$ 4,832	*9.7*	$	....	$ 855	*3.6*
Soldiers' Benefits	....	....		......	86	*.4*
Health and Sanitation	10,117	*20.3*	735	*7.4*	641	*2.6*
Recreation		......	......	......	209	*.9*
Correction	2,558	*5.1*	847	*8.6*	......	......
Total	**17,507**	**35.1**	**1,582**	**16.0**	**1,791**	**7.5**
	Towns over 5,000		Cities		Total	
Charity	1,870	*3.5*	12,042	*5.5*	19,599	*5.5*
Soldiers' Benefits	184	*.3*	1,070	*.5*	1,340	*.4*
Health and Sanitation	3,766	*7.1*	18,702	*8.5*	33,961	*9.5*
Recreation	946	*1.8*	6,090	*2.7*	7,245	*2.0*
Correction	....	....	..	..	3,405	*.9*
Total	**6,766**	**12.7**	**37,904**	**17.2**	**65,550**	**18.3**

with one-half in 1910. The relative amount paid by the State has declined from 33 per cent in 1910 to 27 per cent in 1926. Counties and small towns pay 5 per cent and the relative amount has not changed appreciably since 1910.

Over $33,000,000 were spent for public health and sanitation in 1926 (Table 31); and if recreation is included, nearly two-thirds of the total expenditures for this group were for the improvement of public health. Over $19,000,000 were for charitable purposes, amounting to 30 per cent of the group expenditures, but only 5 per cent of all expenditures. Cities and the State support 86 per cent of the charitable activites, the towns spending one-seventh of the total, the counties nothing.

Table 32 shows the percentage distribution of expenditures for charity, health and correction among the civil groups. The State and counties spend most for correction, while practically all expenditures for recreation are made by cities or large towns. All civil groups spend a part of their appropriations on some phase of public health or sanitation, and expenditures for these purposes tend to increase in importance with the size of the city or town.

Table 32.—Distribution of Expenditures for Charity, Health and Correction, by Jurisdictions, 1926.
(Percentages)

Purpose	Central State Gov't	Counties	Towns Under 5,000	Towns Over 5,000	Cities	**All Groups**
Charity	24.7	......	4.4	9.5	61.4	**100.0**
Soldiers' Benefits	..	....	6.4	13.7	79.9	**100.0**
Health and Sanitation	23.8	1.7	1.5	8.9	44.0	**100.0**
Recreation	......	....	2.9	13.1	84.0	**100.0**
Correction	75.2	24.8	....		...	**100.0**
Total	**26.7**	**2.4**	**2.7**	**10.3**	**57.9**	**100.0**

State Expenditures for Charity, Health and Correction[10]

The State carries on activities of this nature which municipalities can not perform to advantage.

The *Department of Mental Diseases* is concerned with the mental health of the citizens of the Commonwealth. This department spent $8,173,000 in 1926, or about one-sixth of the total State expenditures. Of this amount, $7,826,000 were on account of institutions, including twelve state hospitals for the insane, and three schools and one colony for the feeble-minded and mentally deficient.

Expenditures of the *Department of Public Welfare* in 1926 amounted to $4,832,000. The more important activities of this department include the care of neglected children, the maintenance of a hospital school for crippled children, and the maintenance of four schools for the training of juvenile delinquents. Under the division of general aid and relief $1,732,000 were paid out as reimbursment to the cities and towns for aid to mothers with dependent children, and in connection with contagious diseases, and the support and burial of paupers.

The *Department of Public Health* expended $1,944,000 in 1926. Of this amount $1,472,000 were used by the division of tuberculosis, principally for the maintenance of state tuberculosis hospitals and for subsidies to cities and towns maintaining such hospitals. Minor activities are the enforcement of food and drug laws, sanitary regulations and the regulation of communicable diseases.

The *Department of Correction* expended $2,558,000 in 1926. Of this amount $2,360,000 were for the support of institutions including the state prison, the state farm, the prison camp and hospital, and two reformatories.[11]

State or military aid is given to soldiers, sailors, marines, and army or navy nurses, and to such of their dependents as comply with certain regulations. This aid is usually granted directly by the city or town and reimbursement is made by the State Commissioner of State Aid and Pensions. In 1926 such reimbursement to cities and towns amounted to $295,000 out of a total of $330,000.

Municipal Expenses for Charity, Health and Correction

Table 33 shows the per capita payments for such activities in towns classified according to population in 1926. Payments for each activity show a tendency to increase with population, but charity and soldiers' benefits show less variation than the other items. This group of activities takes from two to four times as much of the budget in cities as in the 83 towns with less than 1,000 population.

Per capita expenditures for health in the small towns are only half those for charity, while in the large towns and cities payments for health average almost twice those for charity. However, in view of differences in the cost of living, it seems probable that small town expenditures for charity are approximately equal to those of larger towns and cities. Small towns do not need as elaborate sanitary systems and regulations as the larger towns and cities, but it is a question whether present low expenditures per capita adequately meet local health requirements. It seems likely that the disproportionate amounts spent for schools and roads prevent many welfare activities in small towns.

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[10] A detailed statement of the activities of the State is contained in the annual reports of the various departments and divisions. The summary presented here is intended to give only a general idea of the scope and cost of State activities.

[11] In Table 30 the cost of juvenile training schools was included under correction, since this is the practice in most states.

Low per capita expenditures for recreation also point to a significant deficiency in small towns. The need for some type of recreation is at least as great in small towns as in cities, but the small number of people concerned, together with high taxes for ordinary purposes, have limited appropriations for recreational purposes.

Table 33.—Expenditures per Capita for Charity, Health and Recreation, by Size of City or Town, 1926.

Size of City or Town	Number of Cities or Towns	Charity	Soldiers' Benefits	Health and Sanitation	Recreation	Total	*Per Cent of Total Expenditures*
Towns							
Under 1000	83	$1.49	$ .19	$1.20	$ .21	$3.09	*4.50*
1000-2000	74	2.10	.23	1.46	.46	4.25	*6.90*
2000-3000	39	2.37	.22	1.79	.88	5.26	*8.20*
3000-4000	28	2.08	.20	1.90	.52	4.70	*9.20*
4000-5000	17	2.14	.20	1.35	.28	3.97	*7.60*
5000-7000	26	2.26	.22	2.32	.45	5.25	*9.60*
7000-10000	22	2.19	.27	4.60	.81	7.87	*11.80*
10000-15000	19	2.83	.23	3.60	.93	7.59	*12.65*
Over 15000	12	1.76	.18	6.87	2.05	10.86	*14.77*
Cities							
Under 25,000	13	2.35	.43	3.62	.71	7.11	*11.83*
25,000-50,000	11	3.18	.38	4.35	1.19	9.10	*14.50*
50,000-75,000	5	3.54	.27	7.52	1.83	13.16	*16.20*
75,000-100,000	2	1.90	.33	4.93	2.65	9.81	*19.60*
100,000-150,000	6	3.13	.35	6.84	1.57	11.89	*17.50*
150,000-200,000	1	5.30	.22	6.63	.89	13.04	*19.00*
Over 200,000	1	6.75	.44	8.16	3.84	19.19	*18.90*

General Government

In the summary tables all other government costs not specifically classified were grouped into "other general". This group includes all activities connected with the assessment and collection of taxes, the protection of persons and property, pension payments, and the maintenance of minor departments of the State government. In 1926, other general expenditures amounted to $65,956,000, or 18 per cent of all public expenditures. The increase in expenditures for this group of activities since 1910 has been relatively less than for other functions. The amounts for each civil group are shown in Table 34.

State Activities[12]

The executive, judicial, legislative and financial functions of the State take approximately 10 per cent of total State expenditures. In addition, eight departments concerned with enforcing certain regulations as part of the police power of the State, and in rendering service to business and industrial groups, have been included in "other general".[13]

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[12] A detailed analysis of expenditures of the State government for general purposes is contained in Table A12.

[13] The departments of conservation, agriculture, banking and insurance, civil service and registration, industrial accidents, labor and industries, public safety, public utilities.

Table 34.—"Other General" Expenditures, by Jurisdictions, 1910-1926.[1]
(Thousands of dollars)

Year	Central State Gov't	Counties	Towns Under 5,000[2]	Towns Over 5,000[2]	Cities[2]	Total
1910	$5,105	$ 2,396	$ 1,226	$ 2,968	$ 14,332	$ 26,027
1911	5,024	2,176	1,294	3,056	14,918	26,468
1912	5,786	2,080	1,934	3,359	16,324	29,483
1913	6,097	2,214	2,011	3,498	17,717	31,537
1914	6,368	2,290	1,693	3,788	18,101	32,240
1915	7,501	2,281	1,849	3,729	17,793	33,153
1916	7,008	2,434	1,790	3,713	18,387	33,332
1917	9,143	2,351	1,969	3,949	20,584	37,996
1918	10,306[3]	2,491	1,969	4,013	22,458	41,237
1919	26,325[3]	2,809	2,195	4,648	27,939	63,916
1920	13,018[3]	3,114	2,470	5,462	29,165	53,229
1921	9,022	3,452	2,797	5,980	32,832	54,083
1922	8,947	3,643	3,020	6,245	33,619	55,474
1923	8,863	3,865	3,066	6,407	35,270	57,471
1924	9,233	4,920	2,992	7,054	37,310	61,509
1925	9,442	5,124	3,190	7,481	39,573	64,790
1926	8,976	5,017	3,302	8,171	40,490	65,956

[1] Includes new construction.

[2] Payments for both maintenance and construction are shown in Table A 1.

[3] Increase due to soldiers' bonus.

Municipal Activites

The two principal groups of municipal expenditures under "other general" are general government and protection of persons and property. General government includes the legislative, executive and financial functions as well as the care of municipal buildings, and minor general departments. Protection of persons and property includes police and fire departments, support of the militia, inspections, and forestry. Expenditures for police and fire protection make up 95 per cent of total expenditures for protection. The amounts spent for general government and for protection are shown in Tables 35 and 36.

Table 35.—Expenditures for General Government.
(Amounts in thousands of dollars)

Year	Cities		Towns over 5,000		Towns under 5,000	
	Amount	*Per cent of Total Expenditures*	Amount	*Per cent of Total Expenditures*	Amount	*Per cent of Total Expenditures*
1910[1]	$3,288	*4.2*	$ 708	*4.1*	$ 442	*7.2*
1915	3,425	*3.4*	943	*4.5*	667	*6.6*
1920	5,134	*3.4*	1,387	*4.2*	906	*5.7*
1925	6,641	*3.2*	2,015	*4.0*	1,132	*5.0*
1926	7,195	*3.3*	2,294	*4.3*	1,220	*5.1*

[1] Not all towns reported in 1910.

Table 36.—Expenditures for Protection of Persons and Property.
(Amounts in thousands of dollars)

Year	Cities		Towns over 5,000		Towns under 5,000	
	Amount	*Per cent of Total Expenditures*	Amount	*Per cent of Total Expenditures*	Amount	*Per cent of Total Expenditures*
1910[1]	$9,461	*12.4*	$1,745	*9.8*	$ 490	*8.0*
1915	11,820	*11.8*	2,140	*10.1*	749	*7.4*
1920	19,717	*13.1*	3,154	*9.6*	1,075	*6.7*
1925	25,970	*12.6*	4,491	*9.0*	1,578	*7.0*
1926	27,216	*12.4*	4,896	*9.2*	1,618	*6.8*

[1] Not all towns reported in 1910.

Expenditures Per Capita for General Government and for Protection of Persons and Property

Table 37 shows the per capita payments for these purposes for towns classified according to population. The cost per person for general government is greater in small towns than in the larger towns and cities. Payments for protection tend to vary in direct proportion to population, and the amount per capita spent in cities is over three times the amount spent in towns of less than 1,000 population. Expenses for protection take only 2.68 per cent of total expenditures in the smallest towns, but over 12 per cent in cities.

Town Expenditures Required by Law

A considerable part of the cost of government in small towns is due to certain legal requirements. These requirements take various forms, but may be roughly classified into three groups.

1. The performance of certain town activities is required by law.
2. The manner of performance of certain functions is frequently prescribed by law.
3. Minimum expenditures for the performance of certain functions are occasionally specified, or the granting of State aid is made contingent upon the town's spending a minimum amount for the purpose for which aid is granted.

Under the first two classes are included the general governmental activities of the town. The town officers and their duties, the method of keeping accounts and the forms of numerous reports required by the various state departments are specified by law. The most important legal requirements are in connection with education and highways.

Every town is required to provide educational facilities for children residing within the town. The State specifies certain subjects to be taught, a minimum term of 160 days, and a salary of at least $750 for each full-time teacher.[14] Every town of more than 500 families must maintain a high school in which a four-year course is taught for a minimum term of 180 days. Towns

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[14] Legal requirements for schools, General Laws, Chapter 71.

Table 37.—Expenditures per Capita for General Government and for Protection of Persons and Property, by Size of City or Town, 1926.

Size of City or Town	Number of Cities or Towns	General Government: Maintenance	General Government: Outlays	General Government: **Total**	General Government: *Per cent of Total Expenditures*	Protection of Persons and Property: Maintenance	Protection of Persons and Property: Outlays	Protection of Persons and Property: **Total**	Protection of Persons and Property: *Per cent of Total Expenditures*
Towns									
Under 1,000	83	$3.28	$ .06	**$3.34**	*4.87*	$1.54	$ .30	**$1.84**	*2.68*
1,000-2,000	74	3.12	.16	**3.28**	*5.36*	2.99	1.20	**3.19**	*5.19*
2,000-3,000	39	3.12	.37	**3.49**	*5.42*	4.72	.46	**5.18**	*8.02*
3,000-4,000	28	2.52	.02	**2.54**	*4.98*	3.34	.83	**4.17**	*8.18*
4,000-5,000	17	2.25	.05	**2.30**	*4.44*	2.79	.35	**3.14**	*6.04*
5,000-7,000	26	2.21	.81	**3.02**	*5.52*	3.10	.33	**3.43**	*6.30*
7,000-10,000	22	2.38	.15	**2.53**	*3.79*	4.76	.73	**5.49**	*8.22*
10,000-15,000	19	2.14	.53	**2.67**	*4.45*	4.73	.35	**5.08**	*8.47*
Over 15,000	12	2.50	.39	**2.89**	*4.07*	7.42	1.21	**8.63**	*11.74*
Cities									
Under 25,000	13	2.44	.37	**2.81**	*4.68*	6.34	.39	**6.73**	*11.20*
25,000-50,000	11	2.20	.59	**2.79**	*4.45*	7.11	.43	**7.54**	*12.10*
50,000-75,000	5	2.59	.02	**2.61**	*3.22*	8.45	.70	**9.15**	*11.28*
75,000-100,000	2	1.57	.04	**1.61**	*3.22*	6.76	.11	**6.87**	*13.75*
100,000-150,000	6	2.35	.11	**2.46**	*3.61*	8.52	.18	**8.70**	*12.80*
150,000-200,000	1	1.96	.01	**1.97**	*2.87*	9.22	.72	**9.94**	*14.49*
Over 200,000	1	2.47		**2.47**	*2.43*	11.99	.49	**12.48**	*12.28*

of less than 500 families may maintain a high school, but if not, the town must provide tuition, and transportation up to 40 cents per day, for all pupils who desire to attend high school and who are properly certified by the town school committtee. Where the distance to a school within the town is greater than two miles the town must furnish transportation to pupils. Towns are also required to provide a school physician and a nurse, except that towns with a valuation of less than $1,000,000 may be exempt from the requirement of a school nurse. Where three or more towns form a superintendency union, the State specifies the minimum salary to be paid the superintendent. Furthermore, only teachers and superintendents who are approved by the State Department of Education may be employed by the town school committee.

In connection with the granting of State aid for education, it has already been pointed out that grants from the Income Tax Fund are in proportion to salaries paid, thereby inducing the towns to pay higher salaries to teachers. Reimbursement from the Massachusetts School Fund is made only to towns in which the school tax is $5.00 or more per $1000 valuation, and the grant is in proportion to the size of the tax. Reimbursement for high school tuition and transportation for pupils attending school in other towns is proportional to the school tax. These are several encouragements offered the towns to develop their school system which involve increasing local taxes.

The legal requirements for town expenditures on highways are principally in connection with State highways. Before the era of automobile registration fees it was customary to build State highways from bond issues. One-fourth of the cost of highways financed in this manner was assessed against the county in which the road was built. The amount so assessed was paid within six years with interest at 6 per cent. Since the counties have no important sources of revenue other than the county tax levied on the towns, it followed that the towns formerly paid one-fourth the cost of State highways financed by loans. This liability is diminishing since most State highways are now being built from motor vehicle fees.

The cost of maintaining State highways is high, and one-half of the amount spent for the maintenance and repair of State highways is assessed against the town in which the repairs are made. On the other hand, the burden of this requirement has been minimized by two provisions: (1) The maximum amount which can be assessed under this section is proportional to the valuation of the town as follows:

Town Valuation	*Maximum Assessment per Mile*
Less than $1,000,000	$ 50.00
1,000,000 - 2,000,000	100.00
2,000,000 - 5,000,000	200.00
Over 5,000,000	$500 in any year, total of $2000

(2) If the assessments are burdensome the selectmen of the town may petition the State highway department for exemption, and if such exemption is granted the State bears the entire cost.

Towns are of course required by law to keep all town roads in repair so that they are reasonably safe for travel, and a further incentive for good roads is given by making the towns liable for damages, either property or personal, sustained on roads not in good repair. All roads not State highways but constructed in whole or in part with money furnished by the State must be kept in repair by the towns in which they are located; and in case the town does not make necessary repairs, the State division of highways may make the repairs and add the cost to the State tax for that town.

Until recently towns were required to keep all highways within their boundaries, including State highways, sufficiently clear of snow and ice to be reasonably safe for travel. As a result, in some of the hill towns costs of snow removal have occasionally equalled the expenditures for highway repairs. The State division of highways is now responsible for keeping State highways open. Snow removal by towns is confined principally to main roads, usually surfaced through routes whether of State, county or town construction.

The cost of making suitable highway improvements is so great that many towns are unable to finance necessary improvements without aid from the State. With one exception such State aid is conditional upon the town's spending a minimum amount, and while this amount is based upon the ability of the town to pay, the net effect is to increase town expenses.

The benefits of such State aid are not questioned, but it should be recognized that too many forms of State aid which require additional expenditures by the town may cause some towns to spend more than they can afford. In general, all of the requirements that have been suggested and discussed are reasonable and proper. It must be admitted that in all cases where minimum compensation for service is fixed by law, the amount is low and imposes no hardship on the town. The effect of prescribed forms, reports and methods of performing various functions has been to bring more system into small town finances with a consequent increase in efficiency.

SOURCES OF FUNDS TO MEET INCREASING EXPENDITURES[15]

Increasing expenditures have made it necessary to find additional funds. Three methods have been used.

1. Taxation
    a. By increasing existing taxes
    b. By levying new taxes
2. Increasing departmental earnings
3. Borrowing

The Increase in Taxes

Table 38 shows the increase in tax levies since 1910. Taxes for State and local purposes in 1926 were $278,000,000, or more than three times as much as in 1910. In addition, federal internal revenue amounting to $119,000,000 was collected in Massachusetts, making a total of over $396,000,000 in taxes paid by the people and industries of the Commonwealth. (Chart 8). Federal internal revenue from Massachusetts in 1926 was more than 20 times as much as in 1910.

The relation betweeen taxes for State purposes and the cost of government is shown on Chart 9. About 70 per cent of the cost of government is met by taxes, and this percentage has remained fairly constant since 1910. Taxes have increased rapidly since 1919 in order to keep pace with increasing expenditures.

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[15] Data on sources of funds have been taken from the following sources: Annual Reports of the State Auditor, Mass. Pub. Doc. 6; Annual Reports of the Commission on Administration and Finance, Mass. Pub. Doc. 140; Annual Reports on the Statistics of County Finances, Mass. Pub. Doc. 29; Annual Reports on the Statistics of Municipal Finances, Mass. Pub. Doc. 79; Annual Reports of the Commissioner of Corporations and Taxation, Mass. Pub. Doc. 16; Annual Reports of the Commissioner of Internal Revenue, U. S. Treas. Dept. Doc.

CHART 8. Taxes Collected for State and Local Purposes, and for All Purposes, Including Federal Internal Revenue, 1910-1926.

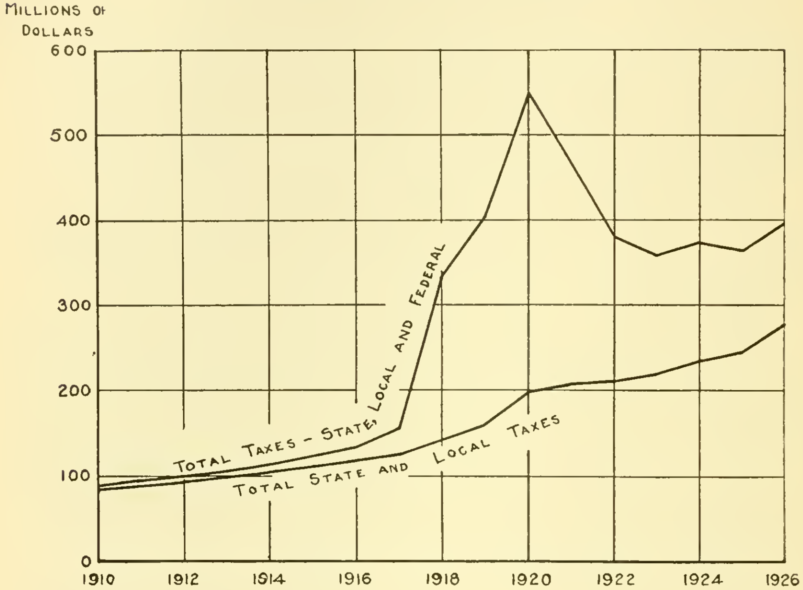
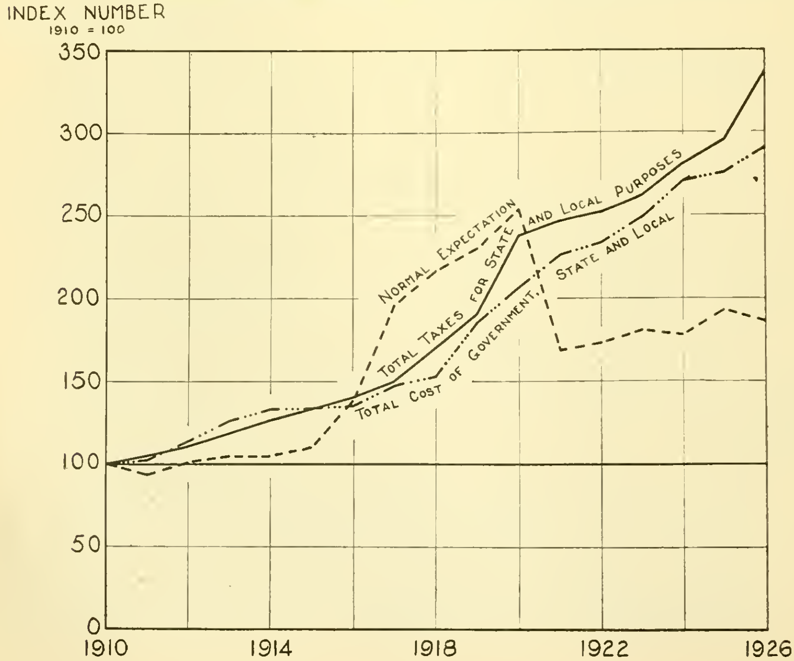
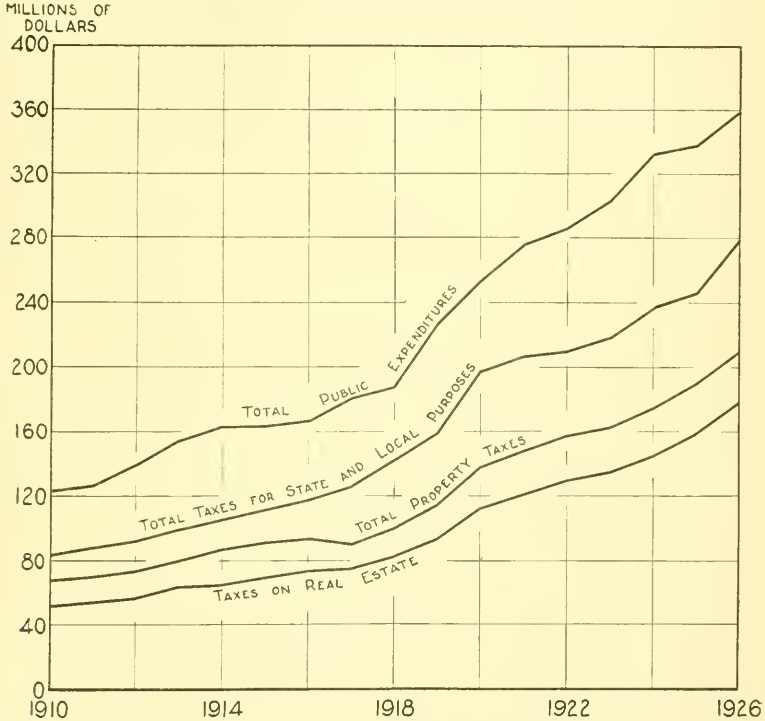


CHART 9. Taxes and Cost of Government Compared with the Normal Expected Increase if Both Changed with Population and the Price Level, 1910-1926. (Expressed in Index Numbers with 1910 as the Base.)



The largest increase has been in property taxes, from $67,000,000 in 1910 to $210,000,000 in 1926, an increase of $143,000,000 or more than 200 per cent. This increase in property taxes makes up nearly three-fourths of the total increase in taxes since 1910. In comparison, taxes on corporations, including income and excise taxes, have increased 85 per cent. Inheritance taxes collected in 1926 amounted to nearly $7,000,000, or more than four times the amount collected in 1910. The poll tax, which is one of the oldest taxes, has increased nearly 31 per cent, or at about the same rate as population. The increase in poll taxes from 1920 to 1923 was due to a special tax for the soldiers' bonus.

CHART 10. A Comparison of Public Expenditures with Total Taxes, Property Taxes, and Taxes on Real Estate, 1910-1926.



The Relative Importance of Different Taxes

The relative importance of the various taxes is shown in Table 38 and in Chart 10. It will be noted that property taxes make up over three-fourths of all taxes collected for State and local purposes. Corporation taxes, the next group in importance, are less than 10 per cent of the total, while all of the remaining taxes are only about one-eighth of the total. The importance of property taxes has been decreasing slightly with the introduction of new taxes; although in 1910 property taxes were 80 per cent of the total collected.

Federal internal revenue now makes up nearly one-third of the total taxes collected in Massachusetts as compared with about 7 per cent in 1910.

Table 38.—Moneys Raised for All Purposes, Including Federal Internal Revenue, 1910-1926.

Year	Corporation Tax[1]	Inheritance Tax	Income Tax[2]	General Property Tax	Poll Tax	Motor Vehicle Licenses	Other	Total for State and Local Purposes	Federal Internal Revenue	Grand Total
1910	$12,659,313	$1,467,697	$	$ 66,716,764	$1,872,612	$ 375,676	$	$ 83,092,062	$ 5,676,103	$ 88,768,165
1911	13,449,798	2,029,225	....	69,392,395	1,897,134	477,565	....	87,246,117	7,397,001	94,643,118
1912	13,985,391	2,154,406	....	73,181,092	1,930,938	616,287	....	91,868,114	7,223,431	99,091,545
1913	13,790,580	2,283,674	....	79,714,023	1,968,084	764,156	....	98,520,517	7,236,812	105,757,329
1914	13,285,721	2,277,832	....	85,971,089	2,012,464	926,183	207	104,473,496	9,116,790	113,590,286
1915	13,158,181	3,204,177	....	90,880,467	2.055.772	1,201,968	242,178	110,742,743	12,094,625	122,837,368
1916	14,923,767	4,223,843	....	93,684,010	2,087,046	1,564,332	305,529	116,788,527	16,059,024	132,847,551
1917	14,888,846	3,900,247	12,540.561	89,331,511	2,163,960	1,962,149	148,906	124,936,180	29,796,108	154,732,288
1918	17,020,950	5,841,204	14,956,925	99,691,883	2,108,400	2,152,977	112,707	141,885,046	191,814,297	333,699,343
1919	18,264,379	5,002,697	15,771,670	114,359,994	2,105,672	3,131,960	214,248	158,850,620	245,731,169	404,581,789
1920	29,108,577[3]	4,607,663	17,698,800	137,354,481	5,048,850	3,267,131	264,172	197,349,674	352,022,233	549,371,907
1921	26,248,899[3]	7,322,947	15,123,905	147,813,267	5,072,435	4,644,605	191,144	206,417,202	259,865,214	466,282,416
1922	20,493,059	6,805,977	13,317,137	157,130,522	5,771,158	5,620,916	219,633	209,358,402	169,813,493	379,171,895
1923	21,429,880	6,158,924	14,782,204	161,837,401	5,835,915	7,720,808	207,249	217,972,381	139,094,000	357,066,381
1924	23,991,455[3]	6,489,173	17,210,349[4]	174,597,600	2,395,736	7,949,625	219,589	232,853,527	138,681,000	371,534,527
1925	21,365,645	5,920,307	16,893,022	189,246,767	2,447,514	9,459,808	299,173	245,632,236	118,909,000	364,541,236
1926	24,473,959	6,827,729	21,772,325	209,559,647	2,451,886	12,645,878	322,298	278,053,722	118,847,761	396,901,483

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[1] Annual assessments. Does not compare with collections which include abatements, additional assessments and assessments of previous years.

[2] Amounts levied corrected through 1926.

[3] Includes special levy.

[4] Includes 10% special levy.

New Taxes[16]

While the principal increase has been in property taxes, two new taxes have been introduced since 1910 that add a substantial amount to total tax levies. The income tax introduced in 1917, together with automobile registration fees, furnishes 8.7 per cent of total taxes for State and local purposes. The entire income tax, less the cost of collection, is distributed to cities and towns. The fees from automobile registration, together with drivers' licenses and court fines for highway penalties, make up most of the revenue of the State highway division. While not a new source in the strict sense of the word, higher registration fees, together with increase in total collections, have made this source of revenue more important to the State government than any other.

Massachusetts was one of the first group of states to use a State income tax as a partial substitute for a property tax on intangible property. The tax has been in operation for twelve years and has been successful not only in raising additional revenue but in partially equalizing the tax burden between owners of real property and the owners of intangibles. It has also brought about a better distribution of taxes between property owners and the salaried groups not previously contributing directly to the cost of government.

Massachusetts was one of the first states to study systematically the problem of taxing corporations. As a result there are now approximately twenty-five taxes applying to different types of corporations. More than one-half of all corporation taxes collected are distributed to cities and towns on various bases. The total estimated corporation taxes for State, local and federal purposes are shown on Chart 11.

The Tax Rate

The tax rate per $1000 assessed valuation is commonly used as a measure of the increase in taxes as well as of tax differences between towns. In 1926 the tax rates of the various cities and towns in Massachusetts varied from $10 to $50.40 per thousand of valuation with an average rate of $30.34 for the state. Table 39 shows the number of cities and towns having various rates in selected years.

Table 39.—Tax Rate in Cities and Towns, for Selected Years.

Tax Rate in Dollars per $1,000 Valuation	Number of Cities or Towns			
	1910	1915	1920	1925
$ 0.10-10.00	21	10	6	1
10.10-20.00	284	222	87	29
20.10-30.00	49	121	211	195
30.10-40.00	0	0	48	127
40.10-50.00	0	0	2	3

From Table 39 it appears that in 1925 only 30 cities and towns had rates of $20.00 or less, while in 1910, 305 were below this figure. Since 1920, rates have varied more between municipalities than in previous years, due to the increase in expenditures and to the failure of many towns and cities to raise

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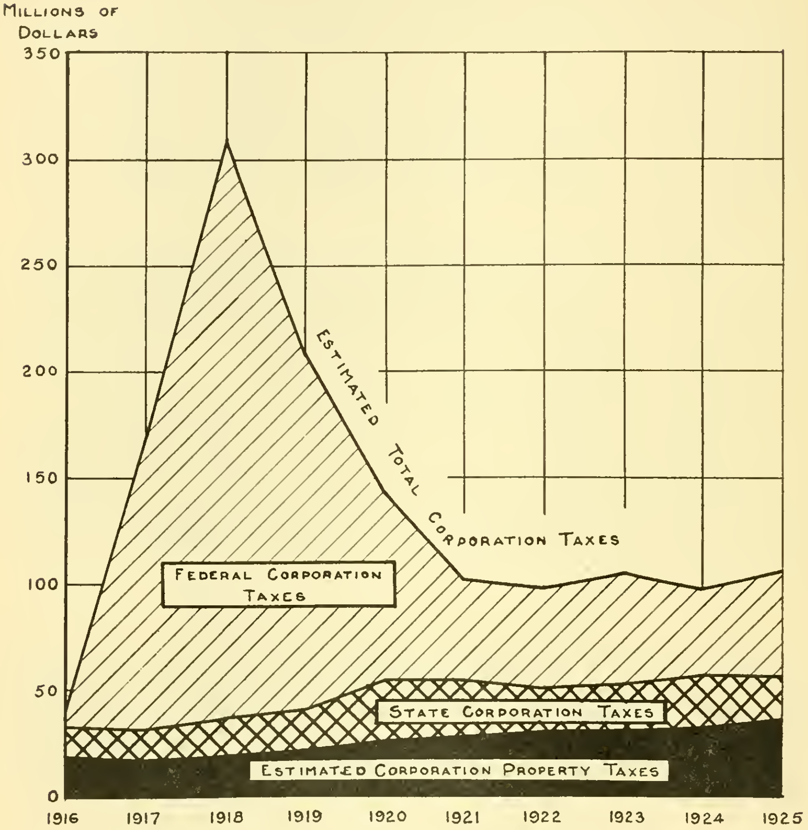
[16] Since this was written, the gasoline tax has been added, and the automobile excise tax has replaced the local taxation of motor vehicles.

CHART 11. Total Taxes Paid by Massachusetts Corporations for All Purposes, Including Estimated Local Property Taxes and State and Federal Taxes, 1916-1925.



assessed valuations of property. In 1917 the State income tax law removed intangible property from the jurisdiction of local assessors. Since that time the local tax rate has applied only to real estate and tangible personal property.

The tax rate has been increasing gradually since 1910, indicating that taxes have increased faster than ability to pay as measured by assessed valuation. This is shown by Table 40, obtained by dividing the total property taxes levied each year by the total assessed valuation for that year.

Table 40.—Average Tax Rate per $1,000 Assessed Valuation, 1910-1926.[1]

Year	*Rate*	*Year*	*Rate*	*Year*	*Rate*
1910	$17.07	1916	$18.87	1921	$26.65
1911	17.02	1917	19.90	1922	27.49
1912	17.07	1918	21.03	1923	27.07
1913	17.83	1919	23.32	1924	27.71
1914	18.51	1920	25.65	1925	28.53
1915	19.05			1926	30.34

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[1] Adapted from reports of the Commissioner of Corporations and Taxation.

The rate of $30.34 per $1000 valuation in 1926 is 78 per cent higher than the rate in 1910. It is customary to compare the present situation with that of the pre-war years by using the 1910-14 average for the earlier period. On this basis, the 1926 rate was 73 per cent above the 1910-14 average. The post-war years marked by price inflation and consequent high costs brought about 75 per cent of the increase from 1910 to 1926.

Limitations of the Tax Rate as a Measure of Tax Differences

The tax rate is not an accurate measure of tax differences between towns or cities, nor is it an accurate measure of the increase in taxes within a given city or town. The use of the term, tax rate, for such purposes frequently leads to gross misstatements of fact.

Assessment practice varies considerably between municipalities. If all towns and cities assessed property at the same percentage of full value, the tax rate would be a fair method of comparison. In practice, however, the ratio of assessed to actual values frequently varies as much as 20 to 30 per cent between towns. Many towns meet increasing expenditures by raising the tax rate rather than by bringing assessed values into line with increasing property values. Therefore the tax rate is not a fair basis of comparison in such cases. However, it is a better measure of the increase in taxes for the state as a whole than for the indvidual city or town.

The Burden on Real Estate

In the agitation for tax reduction, considerable attention has been given to the increasing burden on real estate. For the state as a whole taxes on real estate have increased proportionally more than most other taxes. For instance, taxes on real estate increased 246 per cent from 1910 to 1926. During the same period corporation taxes increased 85 per cent. The increase in the in-

Table 41.—Index Numbers of Assessed Valuation, Property and Poll Taxes, 1910-1927.

1910=100

Year	Assessed Valuation				Taxes			
	Real Estate	Land only	Personalty	Total	Total General Property	Real Estate	Poll	Total Local Tax
1910	100	100	100	100	100	100	100	100
1911	104	103	106	104	104	105	101	104
1912	108	107	115	110	110	108	103	110
1913	113	111	120	114	119	118	105	119
1914	116	113	126	119	129	126	107	128
1915	120	116	128	122	131	134	109	135
1916	124	118	137	123	140	137	111	140
1917	128	120	78	116[1]	134	146	115	133
1918	130	121	92	121	149	159	112	148
1919	134	124	99	125	171	181	112	170
1920	147	131	106	137	206	218	270	208
1921	152	132	110	142	221	235	271	223
1922	158	136	108	146	236	252	308	237
1923	167	140	108	153	242	262	311	244
1924	176	144	113	161	262	283	128	258
1925	187	149	115	170	284	309	131	279
1926	196	153	114	177	314	346	131	309
1927	202	152	113	181	313	346	131	308

[1] Income Tax Act went into effect.

come tax from 1917, the first year in operation, to 1926 was about 74 per cent. For the same period taxes on real estate increased 138 per cent. This latter comparison is the more important if income is a fair measure of ability to pay.

The increase in taxes on real estate is more significant when compared with the increase in assessed valuation. Table 41 shows that the index of real estate valuation in 1927 was 202, compared with the index of taxes on real estate of 346. Taxes on real estate have also increased relatively more than total expenditures.

Increasing taxes on real estate are felt more keenly than other taxes because they are such a large percentage of all taxes. However, the importance of the increase is not as great as is generally supposed. The following figures show the percentage relationship of taxes on real estate to total taxes and to total expenditures.

Year	*Ratio of Taxes on Real Estate to Total Taxes for State and Local Purposes (Per Cent)*	*Ratio of Taxes on Real Estate to Total Expenditures for State and Local Purposes (Per Cent)*
1910	61.7	41.9
1915	62.1	42.2
1920	56.7	44.3
1925	64.6	45.3
1926	63.9	49.8

It will be noted that real estate is paying about 2 per cent more of total taxes and 8 per cent more of total expenditures than in 1910. However, the increase of 8 per cent means a change of almost 20 per cent in the ratio of real estate taxes to total expenditures. Approximately one-half of the total expenditures was obtained from taxes on real estate in 1926.

The Increase in Taxes in Agricultural Towns

It has been pointed out that taxes have increased enormously for the state as a whole. In order to determine whether this increase has been greater in agricultural towns than in other towns, seven groups of five adjoining agricultural towns were taken as samples in different parts of the state. The assessed valuations and taxes levied were computed for each group at intervals of five years, as shown in Table 42.

Increases both in assessed valuation and in taxes levied have varied widely for different sections. The Connecticut Valley region shows the greatest increase both in assessed valuation and in taxes. From 1910 to 1925, valuation increased 127 per cent, all property taxes 338 per cent, and all taxes on real estate 325 per cent. The Middlesex section shows the least increase in assessed valuation, only 10 per cent; while all property taxes increased 175 per cent, and real estate taxes 253 per cent. The hill towns in the western part of the state show the lowest increase in taxes of all the section considered. Taking the seven groups together, property taxes increased 218 per cent, and real estate taxes 245 per cent; while the total assessed valuation increased only 66 per cent and real estate valuation only 82 per cent. Taxes increased much faster than assessed values in every section considered.

With one exception assessed values of land have not increased as much as the assessed valuation of all property or of real estate. The Connecticut Valley shows an increase in land values of 134 per cent, and the nearest ap-

Table 42.—Index Numbers of Assessed Valuations and Property Taxes in Thirty-five Agricultural Towns, 1910-1925.

1910=100

Section	Year	Assessed Valuation				Taxes	
		Total	Real Estate	Land only	Personalty	Total General Property	Real Estate
Western Hill	1910	100	100	100	100	100	100
	1915	119	114	111	136	145	138
	1920	142	132	120	174	203	189
	1925	166	155	131	201	260	243
Connecticut Valley	1910	100	100	100	100	100	100
	1915	142	110	144	153	157	154
	1920	206	158	227	238	288	280
	1925	227	175	234	258	438	425
Central Plateau	1910	100	100	100	100	100	100
	1915	124	116	95	155	139	130
	1920	139	133	101	160	277	162
	1925	157	152	111	177	322	313
Northeastern	1910	100	100	100	100	100	100
	1915	153	120	116	91	152	131
	1920	127	136	127	100	187	200
	1925	158	172	157	114	295	324
East Central	1910	100	100	100	100	100	100
	1915	115	126	118	89	132	141
	1920	144	155	132	129	206	219
	1925	173	194	150	120	296	327
Southeastern	1910	100	100	100	100	100	100
	1915	115	122	120	89	128	135
	1920	142	149	145	114	196	205
	1925	202	214	175	153	314	332
Middlesex	1910	100	100	100	100	100	100
	1915	127	113	106	150	151	133
	1920	96	125	115	49	197	250
	1925	110	146	123	51	275	353
Total	1910	100	100	100	100	100	100
	1915	129	122	117	125	143	138
	1920	138	149	142	111	210	233
	1925	166	182	160	121	318	345

proach to this is found in the southeastern section with an increase of 75 per cent.

In order to compare the increase in assessed valuation and property taxes in agricultural towns with the increase in other towns and cities, ten towns and cities with populations between ten and twenty thousand were taken as typical of the large towns and small cities. The increase in the strictly urban districts was shown by data from ten of the larger cities. The comparative data in Table 43 show that assessed valuation increased 113 per cent in the large towns, 66 per cent in the rural towns, and 60 per cent in cities. The small increase in cities is due in part to the operation of the Income Tax Act of 1917. Therefore assessed valuation of real estate furnishes a better means of comparison. The agricultural towns show an increase of 82 per cent compared with 125 per cent for the large towns and 73 per cent for the cities. Land values also increased faster in the large towns. Property taxes have increased in about the same proportion as total assessed valuations, the large towns ranking first, the cities second, with the smallest increase in the agricultural towns. Taxes on real estate in the agricultural towns increased 245 per cent compared with 272 per cent in the large towns and 183 per cent in the cities.

Table 43.—Index Numbers of Assessed Valuation, Taxes, and Tax Rates per $1000 Valuation, in Cities and Towns, 1910-1925.

Year	State Average	35 Farm Towns	10 Manufacturing Towns	10 Cities	State Average	35 Farm Towns	10 Manufacturing Towns	10 Cities
	Total Assessed Valuation				*Assessed Value of Real Estate*			
1910	**100**	100	100	100	**100**	100	100	100
1915	**122**	129	126	118	**120**	122	122	118
1920	**137**	138	177	133	**147**	149	176	139
1925	**170**	166	213	160	**187**	182	225	173
	All General Property Taxes				*Taxes Levied on Real Estate*			
1910	**100**	100	100	100	**100**	100	100	100
1915	**136**	143	148	132	**134**	138	142	131
1920	**206**	210	250	200	**218**	233	245	209
1925	**284**	318	359	262	**309**	345	372	283
	All General Property Taxes, Rate per $1,000 Valuation				*Real Estate Taxes, Rate per $1,000 Valuation*			
1910	**100**	100	100	100	**100**	100	100	100
1915	**111**	111	117	112	**112**	113	116	111
1920	**150**	152	141	150	**148**	157	139	150
1925	**167**	192	168	164	**165**	190	165	164

Apparently taxes in the agricultural communities have not increased as much as in large towns, but somewhat more than in cities. In order to measure accurately the increase in taxes, total property taxes should be compared with the increase in assessed valuation. This is done in the last section of the table where the index of taxes divided by the index of assessed valuation shows the actual increase in taxes or the index of the tax rate. First, comparing all property taxes with the increase in valuation, the farm towns show an increase of 92 per cent in the tax rate, compared with 68 per cent for the manufacturing towns and 64 per cent for the cities. On the same basis taxes on real estate have increased 90 per cent in the agricultural towns, 65 per cent in the manufacturing towns and 64 per cent in cities. The farm towns show a relative increase in property and real estate taxes of 40 per cent more than the manufacturing towns and cities. For the state as a whole the tax rate in agricultural towns increased 37 per cent more from 1910 to 1925 than property taxes in non-farming communities.

There are several reasons for this situation. Property values have increased relatively faster in cities but the difference is partly due to increasing the tax rate in small towns rather than increasing assessed values of real estate.

Cities have relatively more personal property than small towns, and receive more from the income tax. Consequently in the rural sections real estate has had to bear the larger portion of the increase.

Increase in Departmental Earnings

One method of meeting increasing expenditures is to charge for certain public services rendered. Such departmental earnings may arise out of control and regulatory activities involving the issuing of licenses and permits, or they

Table 44.—Receipts of the Central State Government, by Source, 1910-1926.
(Thousands of dollars)

Year	General Property Tax	Corporation Taxes	Inheritance Tax	Motor Vehicle Licenses, Fines and Fees	Departmental	Miscellaneous[1]	Total
1910	$ 5,500	$ 5,311	$ 1,672	$ 404	$ 2,869	$ 2,127	$17,883
1911	5,500	5,428	2,214	504	2,694	2,060	18,400
1912	6,250	5,839	2,154	645	3,220	2,212	20,320
1913	7,989	5,792	2,355	803	3,106	2,249	22,294
1914	8,761	5,399	2,308	966	2,966	2,297	22,697
1915	9,750	5,649	3,283	1,245	3,286	2,569	25,782
1916	8,000	5,870	4,284	1,617	3,570	2,727	26,068
1917	10,921	5,589	3,944	2,046	4,090	2,490	29,080
1918	11,076	9,412	5,882	2,250	5,865	4,554	39,039
1919	11,662	10,466	5,060	3,237	5,392	3,334	39,151
1920	13,293	10,493	4,632	3,413	9,933	7,254	48,018
1921	16,027	12,254	7,360	4,853	6,093	7,397	53,984
1922	12,000	7,989	6,843	5,886	7,110	8,502	48,330
1923	12,000	8,044	6,087	8,143	6,995	7,084	48,353
1924	10,000	11,492	6,313	8,471	7,343	3,674	47,293
1925	12,000	8,316	5,963	10,035	7,270	3,786	47,370
1926	12,000	9,131	6,475	13,265	7,853	2,765	51,489

[1] Includes miscellaneous revenue, licenses and fees, income from sinking and other invested funds, gifts and grants.

Table 45.—Receipts of Counties, by Source, 1910-1926.
(Thousands of dollars)

Year	General Property Tax	Departmental Receipts				Total
		Education	Highways	Health and Correction	Miscellaneous	
1910	$2,703	$30	$686	$138	$506	$4,063
1911	2,657	27	200	133	524	3,541
1912	2,729	26	163	127	497	3,542
1913	2,951	26	217	118	505	3,817
1914	3,149	34	55	109	509	3,856
1915	3,433	53	60	108	594	4,248
1916	3,626	42	102	125	577	4,472
1917	3,857	54	137	133	561	4,742
1918	4,055	68	147	149	515	4,934
1919	4,252	81	227	176	1,005	5,741
1920	4,644	79	855	278	1,153	7,009
1921	5,404	144	4,117	792	1,006	11,463
1922	5,622	167	161	422	1,007	7,379
1923	5,809	205	103	385	1,215	7,717
1924	6,009	251	52	440	7,768[1]	14,520
925	7,138	240	444	592	1,312	9,726
1926	7,497	262	100	629	1.598	10,086

[1] Increase due to special assessment.

may result from the direct shifting of a portion of the cost of service to those who receive the benefits.

The amount of departmental receipts other than taxes is shown in Tables 44 to 48. The amount of such receipts has increased steadily since 1910 for all civil groups. Receipts of the various departments of the State government have more than doubled since that date, in fact the increase has kept pace with the growth of expenditures and the increase in taxes. Many State departments meet a substantial portion of their expenses with their earnings or receipts, and nearly one-sixth of all State revenue is from this source. The department of mental diseases pays more than 10 per cent of all its expenditures from departmental earnings and receipts; the department of education pays nearly one-sixth of its expenses; the department of correction pays almost one-half; and if motor vehicle fees may be regarded as a departmental receipt, the department of public works is self-supporting.

Departmental receipts in towns and cities furnish between 3 and 4 per cent of all revenue at the present time. In small towns the amount of such receipts is small and the relative importance has declined since 1910. In cities the percentage of departmental receipts to total receipts increased from 2.8 in 1910 to 3.2 in 1926.

State Aid in Small Town Receipts

In 1926 more than one-third of the revenue receipts of towns of less than 500 population was from "gifts and grants", principally from the State. More than one-half of the towns and cities of the Commonwealth had a population of 2500 or less, and for this group State aid made up more than 10 per cent of all revenue receipts. The average for the remaining cities and towns was about 1 per cent. For towns of less than 5000 population the ratio of State

Table 46.—Receipts of Towns under 5,000, by Source, 1910-1926.
(Thousands of dollars)

Year	General Property, Poll, and Income Tax	Corporation Taxes	Departmental	Public Service Enterprises	Miscellaneous[1]	Total
1910	$3,780	$ 548	$ 405	$ 239	$ 753	$ 5,725
1911	3,852	638	392	326	730	5,938
1912	5,643	853	589	456	1,087	8,628
1913	5,883	882	626	519	1,138	9,048
1914	5,261	723	496	437	805	7,722
1915	5,900	685	525	492	1,004	8,606
1916	6,619	637	523	512	1,078	9,369
1917	6,918	653	531	544	1,047	9,703
1918	7,224	711	566	566	1,015	10,082
1919	8,307	794	683	614	1,301	11,699
1920	10,409	753	707	693	1,392	13,954
1921	11,098	1,047	684	743	1,508	15,080
1922	12,423	986	734	821	1,808	16,722
1923	13,630	843	732	882	2,140	18,227
1924	13,390	820	871	895	2,067	18,043
1925	14,551	793	692	961	2,283	19,280
1926	15,965	816	672	1,021	2,422	20,896

[1] Gifts, grants and miscellaneous.

Table 47.—Receipts of Towns over 5,000, by Source, 1910-1926.
(Thousands of dollars)

Year	General Property, Poll, and Income Tax	Corporation Taxes	Departmental	Public Service Enterprises	Miscellaneous	Total
1910	$ 9,484	$ 1,196	$ 671	$ 2,193	$ 1,143	$ 14,687
1911	9,665	1,339	703	2,252	1,233	15,192
1912	10,106	1,421	694	2,399	1,246	15,866
1913	10,826	1,361	719	2,556	1,310	16,772
1914	12,190	1,390	776	2,621	1,370	18,347
1915	12,543	1,388	807	2,651	1,395	18,784
1916	13,601	1,351	885	2,793	1,418	20,048
1917	13,500	1,503	829	2,838	1,311	19,981
1918	14,692	1,765	949	2,996	1,215	21,617
1919	16,883	1,973	1,144	3,394	1,321	24,715
1920	20,724	1,838	1,167	3,894	1,089	28,713
1921	22,458	2,481	1,195	3,728	1,202	31,064
1922	25,062	2,205	1,295	4,061	1,716	34,339
1923	26,686	2,072	1,327	4,346	1,617	36,048
1924	29,886	2,276	1,694	4,778	1,694	40,328
1925	31,902	2,107	1,352	5,314	1,723	42,398
1926	35,038	2,278	1,418	5,635	1,816	46,185

aid to total receipts tended to vary inversely with the population. In a few towns this aid was as much as 50 per cent of the revenue receipts, while in some small towns the grants were insignificant.

State aid tends to equalize revenues between towns, and makes possible more uniform governmental service at a lower tax per capita. In 1926 the per capita tax receipts of small towns were from 10 to 20 per cent below those of large towns and cities, while per capita expenditures were about the same.

Table 48.—Receipts of Cities, by Source, 1910-1926.
(Thousands of dollars)

Year	General Property, Poll, and Income Tax	Corporation Taxes	Departmental	Public Service Enterprises	Miscellaneous	Total
1910	$ 43,537	$ 4,746	$ 1,902	$ 9,223	$ 7,979	$ 67,387
1911	45,183	5,115	1,921	9,302	8,861	70,382
1912	47,097	5,059	2,058	9,790	8,557	72,561
1913	49,537	4,933	2,289	10,041	8,805	75,605
1914	52,058	4,598	2,473	10,230	9,008	78,367
1915	57,605	4,824	2,816	10,462	9,314	85,021
1916	60,556	5,740	3,093	11,187	9,510	90,086
1917	60,745	6,623	3,353	11,635	8,849	91,205
1918	72,027	6,969	4,136	12,242	9,260	104,634
1919	85,865	7,748	5,788	13,393	8,998	121,792
1920	97,271	8,327	4,898	14,419	8,062	132,977
1921	101,197	12,714	5,106	15,015	8,598	142,630
1922	111,581	9,167	5,955	15,753	9,895	152,351
1923	119,132	9,925	6,778	16,807	10,369	163,011
1924	125,087	11,514	7,060	17,108	10,763	171,532
1925	132,469	10,469	5,852	16,915	10,313	176,018
1926	151,080	11,203	6,280	17,854	11,711	198,128

THE PUBLIC DEBT

Borrowing has long been the customary method of providing money for the construction of public works.

Money may be borrowed for a short time in order to meet necessary expenses before taxes are collected, i. e., revenue loans; or for a period of years for permanent improvements through the issuing of bonds, notes, or other certificates of indebtedness. Bonds may be issued by the State, by counties, by cities, by towns, and by various fire, water or other improvement districts. The long-time indebtedness is usually spoken of as the public debt. Bonds and notes are either serial, a certain amount of the loan being paid off each year; or sinking fund, in which a certain amount of money is set aside at interest each year to accumulate for the repayment of the entire loan. According to law, all of the recent long-time municipal loans have been either serial bonds or notes.

In the discussion of the public debt, the following terms have been used. Net debt refers to the outstanding debt exclusive of sinking funds. State debt refers to the direct indebtedness of the State government. Contingent debt is the indebtedness which has been incurred by the State for the benefit of the municipalities in the Metropolitan Boston district. This contingent debt is legally a direct obligation of the State, but the entire charge for interest and serial payments is borne by the municipalities. Enterprise debt refers to the debt which has been incurred in the establishment of public service enterprises. General debt is used to describe that incurred for purposes of general government other than public service enterprises. Municipal debt is that incurred by towns and cities whether for general purposes or for public service enterprises.

The Amount of Debt[17]

The total net outstanding State and municipal debt at the beginning of 1927 was slightly more than $335,000,000. Of this amount, municipal debt made up $270,000,000 or 81 per cent. The remainder was State debt of which $50,000,000 was contingent debt chargeable to municipalities in the Metropolitan Boston area. Therefore, over 95 per cent of the net outstanding public indebtedness is a direct obligation of the cities and towns. The net State debt for general purposes was only $16,168,000 at the beginning of 1927. Approximately one-fourth of the municipal debt is for public service enterprises such as gas, electric light, and water companies. The net general debt incurred either by or for cities and towns (including State contingent debt) was $250,000,000, or more than 90 per cent of the total net general debt. (Table 49).

The greatest increase has been in the city debt, but the percentage increase has been greatest in towns of over 5,000 population. The net general debt of cities increased only 45 per cent from 1910 to 1926, while in towns over 5000 the increase was 118 per cent. The increase of 90 per cent in the indebtedness of towns under 5000 is an understatement of the true situation, since there are fewer towns of this class now than in 1910. Making full allowance for the shifts of towns from one group to another, the rate of increase has been much greater for the towns than for the cities.

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[17] Statistics on debt were obtained from the following sources:
Annual Reports of the State Treasurer, Mass. Pub. Doc. 5; Annual Reports of the State Auditor, Mass. Pub. Doc. 6; Annual Reports of the Commission on Administration and Finance, Mass. Pub. Doc. 140; Annual Reports on the Statistics of County Finances, Mass. Pub. Doc. 29; Annual Reports on the Statistics of Municipal Finances, Mass. Pub. Doc. 79.

Municipal indebtedness has been increasing at an average rate of nearly $4,000,000 each year since 1910. Most of this increase has been in general purpose loans for cities and towns. The State debt, both general and contingent, was less in 1926 than in 1910.

Table 49.—Net Municipal and State Indebtedness, 1910-1926.

(Thousands of dollars)

Year	Municipal Debt			State Debt			Grand Total
	Direct	Enterprise	Total	Contingent	Direct	Total	
1910	$120,244	$48,302	$168,546	$60,737	$20,341	$81,078	$249,624
1911	121,339	49,493	170,832	59,907	20,482	80,389	251,222
1912	122,629	51,862	174,491	58,440	20,790	79,230	253,721
1913	129,062	54,687	183,749	57,402	24,281	81,683	265,432
1914	132,429	57,232	189,661	56,442	28,260	84,702	274,363
1915	133,953	60,835	194,788	55,638	30,405	86,043	280,831
1916	135,793	60,508	196,301	55,090	30,577	85,667	281,968
1917	134,327	60,156	194,483	54,325	33,659	87,984	282,467
1918	126,950	58,673	185,623	53,002	32,058	85,060	270,683
1919	130,694	57,519	188,213	51,126	40,433	91,559	279,772
1920	134,091	56,835	190,926	57,108	35,128	92,236	283,162
1921	143,981	57,761	201,742	54,955	29,312	84,267	286,009
1922	156,956	58,017	214,973	53,283	23,713	76,996	291,969
1923	170,568	59,399	229,967	51,731	20,792	72,523	302,490
1924	185,345	61,351	246,696	50,382	18,923	69,305	316,001
1925	193,507	65,121	258,628	51,261	17,655	68,916	327,544
1926	200,478	69,583	270,061	48,976	16,168	65,144	335,205

Causes of the Increase in Public Indebtedness

The war caused a temporary increase in State debt and a temporary drop in municipal debt. Since 1919 the net direct State debt has been reduced by more than one-half, while the municipal debt has increased about 50 per cent. Before the war the annual average increase in net municipal debt was about $5,000,000; since 1920 it has been more than $13,000,000; while during the war there was a decline. The increase has been due to the same factors that caused the increase in all public expenditures.

Considering the rise in prices, the total increase in indebtedness has not been excessive. In terms of 1913 dollars, or in purchasing power, the average annual increase in public debt since 1915 has been less than from 1910 to 1915. On the same basis the large loans from 1920 to 1925 did not make up for the preceding five-year period when few new loans were made.

One method of measuring indebtedness is the ratio of net debt to assessed valuation, provided assessed valuation is comparable to real valuation. From 1910 to 1926 the ratio of net municipal debt to valuation dropped from 4.31 per cent to 3.88 per cent. From 1920 to 1924 the ratio increased, but apparently is again declining. The ratio of total State and municipal debt to assessed valuation has dropped from 6.38 per cent to 4.92 per cent between 1910 and 1926, indicating that for the state as a whole, loans have not been excessive. However, in individual cities and towns the ratio of debt to assessed valuation has been increasing. This increase is explained by low assessed valuation in some instances; in others, it reflects greater optimism on the part of taxpayers or their officials.

The ratio of outstanding debt to annual expenditures is another measure of indebtedness. In 1910 the net outstanding debt was more than double the total expenditures for that year; in 1925 net debt was slightly less than total expenditures. The declining ratio of debt to expenditures indicates that for the state as a whole borrowing has been conservative, or it may even indicate that borrowing has not been equal to needs.

Individual cities and towns have not all followed such a conservative policy. The difference between cities and towns is shown by Table 50.

Table 50.—Ratio of Net Debt to Assessed Valuation, 1926

Group	*General Debt*	*Enterprise Debt*	**Total Debt**
Cities	3.26	1.09	**4.35**
Towns over 5,000	2.37	.59	**2.96**
Towns under 5,000	1.14	.39	**1.53**

Apparently the ratio of debt to valuation tends to increase with the size of the town or city, due partly to the legal restrictions on indebtedness of small towns. Since enterprise debt is usually for the purpose of acquiring or expanding a self-supporting gas, electric, or water plant, the variations in enterprise debt between cities are not especially significant.

Differences between individual cities and towns are much greater than the above table indicates. Thus for the 39 cities, the ratio of total debt to valuation in 1926 varied from 1.54 per cent in Somerville to 6.01 per cent in Revere. Excluding enterprise debt, the ratio of general debt varied from 1.25 per cent in Lawrence to 5.48 in Revere. Differences for the 39 cities were as follows:

Ratio of General Debt to Assessed Valuation (Per cent)	*Number of Cities*
1.00 - 1.99	7
2.00 - 2.99	10
3.00 - 3.99	15
4.00 - 4.99	6
5.00 - 5.99	2

There is no relation between the size of the city and the ratio of debt to assessed valuation.

For towns of more than 5000 population, the range in the ratio of debt to valuation is greater than for cities, Ten towns have ratios above 5 per cent, and in 17 towns the ratios are less than 1 per cent. There is apparently little relation between size of town and ratio of debt to valuation in this group.

Since cities and towns assess property at varying percentages of value, the ratio of debt to valuation is not as significant as it would be if assessment practices were uniform. For some purposes, the net debt per capita is a better measure of the differences between towns and cities. The differences in general debt per capita for cities and for towns over 5000 are as follows:

Per Capita General Debt	*Number of Towns over 5,000*	*Number of Cities*
$ 0 - 19.99	28	4
20 - 39.99	30	10
40 - 59.99	11	18
60 - 79.99	7	5
80 - 99.99	2	2
100 - 119.99	1	0

There is apparently little relation between per capita valuation and per capita debt. Towns of 5000 or more population show greater variation in per capita debt than do cities, and the group average is only $33 compared with $55 for cities. Only ten towns in this group have more than $60 per capita general debt. There is a close correlation between size of town and per capita debt, and most of the high figures are for towns of more than 10,000 population.

Debt in towns of less than 5000 population is not a serious problem. Sixty-six towns in this group reported no debt in 1926, and in many other towns debt incurred for public service enterprises is of more importance than general debt. Only a few towns in which assessed valuations are high reported more than $50 general debt per person. The pay-as-you-go policy adopted by many towns is responsible for low per capita indebtedness. Only four of the 237 towns of this group showed a ratio of general debt to assessed valuation of more than 4 per cent on January 1, 1927.

Summarizing, the total indebtedness of the State and local governments does not appear excessive when considered in connection with the common measures of safety. However, many cities and towns are approaching the danger point if their assessed valuation is a fair measure of ability to pay. Cities and towns vary greatly in per capita indebtedness and in the ratio of debt to assessed valuation. In general the outstanding debt per person is in proportion to the size of the city or town, while there is little relation between valuation and debt. Direct taxes per person tend to increase with indebtedness. This is partly due to the legal requirement that a certain amount of the loan be repaid each year, but principally to the fact that those cities and towns finding it necessary to borrow extensively have already attempted to meet their increasing expenditures by heavier taxes.

APPENDIX

In the following tables, where total expenditures are shown for various functions, payments for both current maintenance and permanent outlays are included unless otherwise stated.

Table A 1.—Expenditures for Various Purposes, 1910-1926.

(Thousands of dollars)

Towns under 5,000

Year	HIGHWAYS			EDUCATION			CHARITY, HEALTH AND CORRECTION		
	Maintenance	Outlays	Total	Maintenance	Outlays	Total	Maintenance	Outlays	Total
1910	$872	$501	$1,373	$1,843	$208	$2,051	$487	$50	$537
1911	879	459	1,338	1,817	193	2,010	474	61	535
1912	1,302	887	2,189	2,714	359	3,073	714	98	812
1913	1,420	1,017	2,437	2,824	487	3,311	762	172	934
1914	1,305	981	2,286	2,461	330	2,791	687	281	968
1915	1,438	1,130	2,568	2,803	387	3,190	798	97	895
1916	1,629	927	2,556	2,946	358	3,304	827	84	911
1917	1,676	918	2,594	3,194	335	3,529	835	90	925
1918	1,707	750	2,457	3,334	111	3,445	895	31	926
1919	2,165	1,288	3,453	3,969	223	4,192	1,105	189	1,294
1920	3,148	1,754	4,902	5,059	355	5,414	1,146	186	1,332
1921	2,928	1,631	4,559	5,841	578	6,419	1,262	255	1,517
1922	2,915	1,922	4,837	6,231	1,001	7,232	1,364	104	1,468
1923	3,559	2,084	5,643	6,620	949	7,569	1,395	142	1,537
1924	3,427	2,398	5,825	6,575	1,355	7,930	1,360	533	1,893
1925	3,500	3,024	6,524	6,913	1,358	8,261	1,570	142	1,712
1926	4,394	3,047	7,441	7,175	1,190	8,365	1,619	172	1,791
Towns over 5,000									
1910	$1,668	$753	$2,421	$3,494	$856	$4,350	$1,369	$719	$2,088
1911	1,697	821	2,518	3,549	789	4,338	1,389	761	2,150
1912	1,771	996	2,767	3,789	759	4,548	1,460	712	2,172
1913	1,870	995	2,865	4,023	982	5,005	1,590	836	2,426
1914	2,193	1,107	3,300	4,532	1,042	5,574	1,862	793	2,655
1915	2,270	1,036	3,306	4,646	981	5,627	1,997	746	2,743
1916	2,356	1,185	3,541	4,812	1,113	5,925	2,071	635	2,706
1917	2,543	1,217	3,760	5,178	1,350	6,528	2,112	657	2,769
1918	2,496	676	3,172	5,559	727	6,286	2,307	373	2,680
1919	3,036	1,308	4,344	6,458	795	7,253	2,771	687	3,458
1920	3,884	1,772	5,656	8,730	1,669	10,399	3,056	852	3,908
1921	3,946	2,448	6,394	9,922	1,832	11,754	3,570	1,141	4,711
1922	3,950	2,190	6,140	10,390	2,861	13,251	3,614	821	4,435
1923	4,197	2,518	6,715	10,875	3,392	14,267	3,669	1,524	5,193
1924	4,533	3,830	8,363	12,000	5,431	17,431	4,156	1,875	6,031
1925	4,754	3,370	8,124	12,676	4,025	16,701	4,511	1,198	5,709
1926	5,613	3,981	9,594	13,374	3,315	16,689	4,871	1,895	6,766
Cities									
1910	$5,925	$3,675	$9,600	$13,174	$2,799	$15,973	$8,481	$3,107	$11,588
1911	5,909	3,141	9,050	13,868	3,244	17,112	8,935	2,869	11,804
1912	6,242	4,159	10,401	14,912	2,719	17,631	9,715	4,028	13,743
1913	6,690	5,289	11,979	15,988	3,103	19,091	10,676	4,354	15,030
1914	6,711	6,519	13,230	16,762	3,934	20,696	11,495	3,945	15,440
1915	6,496	5,631	12,127	17,712	3,445	21,157	12,727	3,792	16,519
1916	7,083	4,615	11,698	18,507	2,986	21,493	12,872	3,499	16,371
1917	7,875	5,014	12,889	19,917	3,734	23,651	14,379	4,103	18,482
1918	8,374	3,805	12,179	21,927	2,423	24,350	15,902	2,687	18,589
1919	10,117	7,433	17,550	24,532	2,162	26,694	18,122	3,553	21,675
1920	12,012	8,514	20,526	33,268	4,607	37,875	21,094	4,531	25,625
1921	11,379	10,379	21,758	37,480	6,747	44,227	23,193	5,599	28,792
1922	10,989	9,660	20,649	39,306	8,402	47,708	23,711	5,622	29,333
1923	12,556	10,329	22,885	42,193	10,402	52,595	25,219	6,889	32,108
1924	12,843	16,168	29,011	44,477	10,538	55,015	28,229	8,084	36,313
1925	11,958	12,997	24,955	45,566	11,490	57,056	29,118	8,189	37,307
1926	14,029	13,819	27,848	49,092	11,725	60,817	30,404	7,500	37,904

Table A. 1.—Expenditures for Various Purposes, 1910-1926.—*Concluded.*
(Thousands of dollars)

Towns under 5,000

OTHER GENERAL			PUBLIC SERVICE ENTERPRISES			TOTAL		Interest and Debt	Grand Total
Maintenance	Outlays	Total	Maintenance	Outlays	Total	Maintenance	Outlays	Total	
$1,117	$109	$1,226	$143	$149	$292	$4,462	$1,017	$648	$6,127
1,163	131	1,294	180	286	466	4,513	1,130	698	6,341
1,686	248	1,934	290	376	666	6,706	1,968	1,059	9,733
1,818	193	2,011	313	667	980	7,137	2,536	1,131	10,804
1,521	172	1,693	267	272	539	6,241	2,036	986	9,263
1,676	173	1,849	290	285	575	7,005	2,072	1,077	10,154
1,609	181	1,790	292	148	440	7,303	1,698	1,133	10,134
1,781	188	1,969	349	138	487	7,835	1,669	1,181	10,685
1,852	117	1,969	430	119	549	8,218	1,128	1,120	10,466
2,018	177	2,195	420	192	612	9,677	2,069	1,158	12,904
2,241	229	2,470	514	202	716	12,108	2,726	1,171	16,005
2,480	317	2,797	544	391	935	13,055	3,172	1,373	17,600
2,600	420	3,020	574	309	883	13,684	3,756	1,404	18,844
2,612	454	3,066	626	346	972	14,812	3,975	1,556	20,343
2,700	292	2,992	611	493	1,104	14,673	5,071	1,549	21,293
2,728	462	3,190	642	586	1,228	15,353	5,562	1,715	22,630
2,929	373	3,302	677	561	1,238	16,795	5,342	1,831	23,968
Towns over 5,000									
$2,770	$198	$2,968	$1,015	$1,502	$2,517	$10,316	$4,028	$3,062	$17,406
2,888	168	3,056	1,071	895	1,966	10,594	3,434	3,244	17,272
3,024	335	3,359	1,237	857	2,094	11,281	3,659	3,256	18,196
3,154	344	3,498	1,246	737	1,983	11,883	3,894	3,456	19,233
3,382	406	3,788	1,328	794	2,122	13,297	4,142	3,788	21,227
3,488	341	3,729	1,405	895	2,300	13,706	3,999	3,425	21,130
3,463	250	2,713	1,515	803	2,318	14,217	3,986	3,598	21,801
3,677	272	3,949	1,655	706	2,361	15,165	4,202	3,713	23,080
3,843	170	4,013	2,082	578	2,660	16,287	2,524	3,753	22,564
4,385	263	4,658	2,143	708	2,851	18,793	3,761	3,601	26,155
5,020	442	5,462	2,706	795	3,501	23,396	5,530	3,826	32,752
5,526	454	5,980	2,552	912	3,464	25,516	6,787	4,120	36,423
5,813	432	6,245	2,664	1,250	3,914	26,431	7,554	4,372	38,359
5,768	639	6,407	2,904	1,391	4,295	27,413	9,464	4,562	41,439
6,276	778	7,054	3,125	2,041	5,166	30,090	13,955	5,155	49,200
6,555	926	7,481	3,397	2,812	6,209	31,893	12,331	5,750	49,974
7,037	1,134	8,171	3,710	2,328	6,038	34,604	12,654	6,158	53,416
Cities									
$13,171	$1,161	$14,332	$3,241	$3,042	$6,283	$43,992	$13,784	$18,249	$76,025
13,538	1,380	14,918	3,330	3,585	6,915	45,580	14,219	18,688	78,487
14,678	1,646	16,324	3,557	4,763	8,320	49,104	17,315	19,162	85,581
15,330	2,387	17,717	3,829	6,420	10,249	52,513	21,553	20,084	94,150
16,196	1,905	18,101	4,010	6,955	10,965	55,174	23,258	20,656	99,088
16,699	1,094	17,793	3,848	6,557	10,405	57,482	20,519	22,394	100,395
17,287	1,100	18,387	4,377	5,354	9,731	60,126	17,554	23,474	101,154
19,403	1,181	20,584	5,387	3,749	9,136	66,961	17,781	23,208	107,950
21,420	1,038	22,458	6,196	2,121	8,317	73,819	12,074	24,451	110,344
27,136	803	27,939	6,137	2,397	8,534	86,044	16,348	24,870	127,262
28,155	1,010	29,165	8,106	3,183	11,289	102,635	21,845	25,870	150,350
30,710	2,122	32,832	7,899	5,163	13,062	110,661	30,010	27,320	167,991
32,030	1,589	33,619	7,621	4,750	12,371	113,657	30,023	30,043	173,723
32,535	2,735	35,270	8,771	5,615	14,386	121,274	35,970	29,439	186,683
34,216	3,094	37,310	8,819	6,197	15,016	128,584	44,081	31,163	203,828
36,794	2,779	39,573	9,175	6,786	15,961	132,611	42,241	31,775	206,627
38,438	2,052	40,490	9,906	8,159	18,065	141,870	43,254	34,791	219,915

Table A 2.—Expenditures per Capita for Various Purposes, by Size of Town, 1912, 1917, 1922, and 1926.

Population	GENERAL GOVERNMENT				PROTECTION				HEALTH AND SANITATION			
	1912	1917	1922	1926	1912	1917	1922	1926	1912	1917	1922	1926
Under 1000	$1.50	$1.76	$4.55	$3.34	$1.18	$ .95	$1.82	$1.84	$ .26	$ .35	$ .77	$1.20
1000-2000	2.13	1.85	2.72	3.28	1.84	2.04	4.41	4.19	.42	.62	1.35	1.46
2000-3000	1.46	1.97	2.72	3.49	2.78	2.69	3.77	5.18	.50	.55	1.49	1.79
3000-4000	1.26	1.59	2.24	2.54	1.48	1.98	3.45	4.17	.71	.71	1.14	1.90
4000-5000	1.43	1.47	1.79	2.30	2.21	1.49	2.06	3.14	.39	.43	.93	1.35
5000-7000	1.58	1.53	2.22	3.02	2.50	2.44	3.98	3.43	1.03	1.64	1.88	2.32
7000-10000	1.42	1.39	2.01	2.53	2.71	2.97	4.68	5.49	1.64	1.46	2.36	4.60
10000-15000	1.22	1.33	2.02	2.67	2.57	2.79	4.47	5.08	1.64	1.45	3.22	3.60
	HIGHWAYS				SCHOOLS				CHARITY			
Under 1000	5.81	7.61	16.76	31.60	7.57	9.56	20.76	23.33	1.08	1.27	1.38	1.49
1000-2000	5.95	6.67	12.40	21.00	7.18	8.60	17.69	19.64	1.35	1.44	2.06	2.10
2000-3000	5.21	6.83	12.62	17.96	6.31	8.24	17.69	20.67	1.40	1.75	4.84	2.37
3000-4000	4.20	5.98	11.18	13.09	6.98	8.14	17.37	17.39	1.06	1.37	2.39	2.08
4000-5000	4.64	4.88	7.30	13.12	6.96	7.60	13.98	20.08	1.32	1.59	2.40	2.14
5000-7000	3.68	5.27	10.66	12.15	7.05	8.58	17.02	18.41	1.24	1.53	2.11	2.26
7000-10000	3.77	5.00	8.13	11.12	6.89	9.71	15.75	20.42	1.11	1.40	2.38	2.19
10000-15000	4.23	5.09	7.74	10.13	5.68	8.74	17.20	19.33	.98	1.52	2.60	2.83

Table A 3.—Relative Importance of Expenditures for Various Purposes, by Size of Town, 1912, 1917, 1922, and 1926.

(Per cent of total expenditures)

	General Government				Protection				Health and Sanitation			
Population	1912	1917	1922	1926	1912	1917	1922	1926	1912	1917	1922	1926
Under 1000	7.2	7.2	8.9	4.9	5.7	3.9	3.6	2.7	1.3	1.4	1.5	1.8
1000-2000	8.7	6.9	5.6	5.4	7.5	7.6	6.9	5.2	1.7	2.3	2.8	2.4
2000-3000	6.1	6.7	5.5	5.4	11.6	9.1	7.7	8.0	2.1	1.9	3.0	2.8
3000-4000	6.0	6.1	4.7	5.0	7.0	7.6	7.2	8.2	3.4	2.7	2.4	3.7
4000-5000	6.2	6.5	5.2	4.4	9.5	6.6	6.0	6.0	1.7	1.9	2.7	2.6
5000-7000	6.2	5 0	4.3	5.5	9.8	8.0	7.7	6.3	4.0	5.4	3.6	4.3
7000-10000	5.2	4.3	4.0	3.8	9.9	9.1	9.4	8.2	6.0	4.5	4.7	6.9
10000-15000	4.9	4.4	3.9	4.5	10.3	5.4	8.7	8.5	6.6	4.8	6.3	6.0
	Highways				Schools				Charity			
Under 1000	28.0	31.2	32.9	49.0	36.5	39.2	40.8	34.0	5.2	5.2	2.7	2.2
1000-2000	24.2	25.0	25.4	34.2	29.2	32.2	36.2	32.0	5.5	5.4	4.2	3.4
2000-3000	21.8	23.1	25.7	27.9	26.4	27.9	36.0	32.0	5.9	5.9	9.9	3.7
3000-4000	19.9	23.1	23.4	25.6	33.0	31.4	36.4	34.1	5.0	5.3	5.0	4.1
4000-5000	20.0	21.7	21.3	25.4	30.0	33.8	40.7	38.8	5.7	7.1	7.0	4.1
5000-7000	14.4	17.3	20.6	22.3	27.6	27.9	33.0	33.8	4.9	5.0	4.1	4.2
7000-10000	13.7	15.4	16.3	16.7	24.9	29.9	31.6	30.5	4.0	4.3	4.8	3.3
10000-15000	16.9	16.8	15.0	16.9	22.7	28.9	33.4	32.2	3.9	5.0	5.1	4.7

Table A 4.—Expenditures for Schools, by Size of Town, 1912, 1917, 1922, and 1926.

Maintenance

Size of Town	1912			1917			1922			1926		
	Amount per Capita	Per cent of School Expenditures	Per cent of Total Expenditures	Amount per Capita	Per cent of School Expenditures	Per cent of Total Expenditures	Amount per Capita	Per cent of School Expenditures	Per cent of Total Expenditures	Amount per Capita	Per cent of School Expenditures	Per cent of Total Expenditures
Under 1000	$7.38	97.4	35.6	$9.46	98.9	38.6	$19.41	93.5	38.3	$22.32	95.7	33.8
1000-2000	6.38	88.8	26.0	8.01	93.1	30.1	15.36	86.8	31.4	18.23	92.8	29.7
2000-3000	5.95	94.2	25.0	7.10	86.1	24.1	14.71	83.1	29.9	16.77	81.1	26.0
3000-4000	5.59	70.1	26.5	7.52	92.3	29.1	14.50	83.5	30.4	15.24	87.6	29.9
4000-5000	5.67	81.4	24.5	6.31	83.0	28.1	11.98	85.7	34.9	14.51	72.3	28.1
5000-7000	5.64	79.9	22.0	7.17	83.5	23.5	14.31	84.1	27.7	15.47	84.0	28.4
7000-10000	5.65	82.0	20.6	6.68	68.8	20.6	13.81	87.7	27.8	15.83	77.5	23.7
10000-15000	4.89	86.0	19.6	6.82	78.1	22.5	13.32	77.4	25.9	14.55	75.3	24.3
Average	5.71	85.3	23.1	8.19	82.2	24.5	14.31	83.8	28.9	16.61	83.3	28.0
Construction and Equipment												
Under 1000	$ .19	2.6	.9	$ .10	1.1	.4	$1.35	6.5	2.7	$1.01	4.3	1.4
1000-2000	.80	11.2	3.2	.59	6.9	2.2	2.33	13.2	4.8	1.41	7.2	2.3
2000-3000	.36	5.8	1.5	1.14	13.9	3.9	2.98	16.9	6.1	3.90	18.9	4.8
3000-4000	1.39	19.9	6.5	.62	7.7	2.4	2.87	16.5	6.0	2.15	12.4	4.2
4000-5000	1.29	18.6	5.6	1.29	17.0	5.8	2.00	14.3	5.8	5.57	27.7	10.8
5000-7000	1.41	20.1	5.5	1.41	16.5	4.6	2.71	15.9	5.3	2.94	16.0	5.4
7000-10000	1.24	18.0	4.5	3.03	31.2	9.3	1.94	12.3	3.9	4.59	22.5	6.9
10000-15000	.79	14.0	3.1	1.91	21.9	6.3	3.88	22.6	7.5	4.78	24.7	8.0
Average	.98	14.7	3.9	1.55	17.8	5.3	2.76	16.2	5.6	3.29	16.7	5.5

Table A 5.—Expenditures for Highways, by Size of Town, 1912, 1917, 1922 and 1926.

Maintenance

Size of Town	1912 Amount per Capita	1912 Per cent of Highway Expenditures	1912 Per cent of Total Expenditures	1917 Amount per Capita	1917 Per cent of Highway Expenditures	1917 Per cent of Total Expenditures	1922 Amount per Capita	1922 Per cent of Highway Expenditures	1922 Per cent of Total Expenditures	1926 Amount per Capita	1926 Per cent of Highway Expenditures	1926 Per cent of Total Expenditures
Under 1000	$3.34	57.4	16.1	4.16	54.7	16.9	$11.41	68.1	22.4	$18.49	58.5	27.0
1000-2000	3.16	53.1	12.9	4.60	69.0	17.3	8.25	66.5	16.9	12.23	58.2	19.9
2000-3000	3.15	50.5	13.2	4.26	62.4	14.4	6.67	52.8	13.6	11.08	61.7	17.2
3000-4000	2.72	64.8	12.9	4.24	71.5	16.4	6.25	55.9	13.1	7.94	60.7	15.6
4000-5000	3.15	68.0	13.6	3.13	64.1	13.9	4.33	59.2	12.6	7.25	55.3	14.0
5000-7000	2.70	73.4	10.6	3.86	73.2	12.7	6.31	59.2	12.2	7.28	59.9	13.4
7000-10000	2.69	71.2	9.8	3.36	67.3	10.4	5.33	65.5	10.7	7.44	66.9	11.1
10000-15000	2.58	61.0	10.3	3.36	66.0	11.1	4.78	61.7	9.3	5.77	57.0	9.6
Average	2.86	63.6	11.5	3.80	66.9	13.0	6.20	61.1	12.5	9.69	59.8	16.0

Construction

Size of Town	1912 Amount per Capita	1912 Per cent of Highway Expenditures	1912 Per cent of Total Expenditures	1917 Amount per Capita	1917 Per cent of Highway Expenditures	1917 Per cent of Total Expenditures	1922 Amount per Capita	1922 Per cent of Highway Expenditures	1922 Per cent of Total Expenditures	1926 Amount per Capita	1926 Per cent of Highway Expenditures	1926 Per cent of Total Expenditures
Under 1000	$ 2.48	42.6	11.9	$ 3.45	45.3	14.1	$ 5.35	31.9	10.5	$13.11	41.5	19.1
1000-2000	2.79	46.9	11.3	2.07	31.0	7.7	4.16	33.5	8.5	8.77	41.8	14.3
2000-3000	2.06	39.5	8.6	2.57	37.6	8.7	5.96	47.2	12.1	6.88	38.3	10.7
3000-4000	1.48	35.2	5.0	1.74	28.5	6.7	4.94	44.1	10.3	5.15	39.3	10.1
4000-5000	1.48	32.0	6.4	1.75	35.9	7.8	2.98	40.8	8.7	5.87	44.7	11.4
5000-7000	.98	26.6	3.8	1.41	26.8	4.6	4.35	40.8	8.4	4.87	40.1	8.9
7000-10000	1.08	28.8	4.0	1.64	32.7	5.0	2.80	34.5	5.6	3.68	33.1	5.5
10000-15000	1.65	39.0	6.6	1.73	34.0	5.7	2.97	38.3	5.7	4.36	43.0	7.3
Average	1.64	36.4	6.6	1.88	33.1	6.4	3.96	38.9	8.0	6.59	40.2	10.9

Table A 6.—Increase in Costs per Capita of Local Government, Schools and Highways, by Size of Town, 1912 to 1926. *(Percentages)*

Population	Total for Local Government	SCHOOLS			HIGHWAYS		
		Maintenance	Construction and Equipment	Total	Maintenance	Construction	Total
Under 1,000	**230.6**	202.4	431.6	**208.2**	453.6	428.6	**443.9**
1,000-2,000	**149.9**	185.7	76.3	**173.5**	287.0	214.3	**252.9**
2,000-3,000	**169.9**	181.8	983.3	**227.6**	251.7	234.0	**244.7**
3,000-4,000	**141.5**	172.6	54.7	**149.1**	191.9	248.0	**211.7**
4,000-5,000	**123.2**	155.9	331.8	**188.5**	130.2	296.6	**182.8**
5,000-7,000	**112.7**	174.3	108.5	**161.1**	169.6	396.9	**230.2**
7,000-10,000	**143.8**	180.2	270.2	**196.4**	176.6	249.1	**195.0**
10,000-15,000	**140.2**	197.5	505.1	**240.3**	123.6	164.2	**139.5**
Average	**149.8**	**190.9**	**235.7**	**197.0**	**238.8**	**301.8**	**261.6**

Table A 7.—Expenditures of Cities and Towns, 1926.[1]
(Thousands of dollars)

	Cities	Towns Over 5,000	Towns Under 5,000
Maintenance	$141,870	$34,604	$16,794
Departmental	*130,847*	*30,613*	*15,960*
General Government	6,725	1,916	1,159
Protection of Persons and Property	26,034	4,325	1,335
Health and Sanitation	13,274	2,119	546
Highways	14,029	5,613	4,394
Charities	11,149	1,852	850
Soldiers' Benefits	1,070	184	86
Schools	46,548	12,750	6,908
Libraries	2,544	623	267
Recreation	4,911	716	137
Pensions	3,296	91	4
Unclassified	1,267	424	274
Public Service Enterprises	*9,906*	*3,710*	*677*
Electric Light	2,023	1,811	294
Water	6,786	1,857	377
All Other	1,098	42	6
Cemeteries	*873*	*277*	*156*
Administration of Trust Funds	*244*	*5*	*1*
Outlays	43,254	12,654	5,342
Departmental	*35,039*	*10,265*	*4,765*
General Government	470	378	60
Protection of Persons and Property	1,182	572	282
Health and Sanitation	5,428	1,647	95
Highways	13,819	3,981	3,047
Charities	893	18	5
Schools	11,599	3,240	1,175
Libraries	125	75	15
Recreation	1,179	230	72
Unclassified	344	124	14
Public Service Enterprises	*8,159*	*2,328*	*561*
Electric Light	699	474	126
Water	4,313	1,845	433
All Other	3,147	9	2
Cemeteries	*56*	*61*	*16*
Interest	15,524	2,429	650
Loans, general purposes	*11,393*	*1,949*	*549*
Loans, public service enterprises	*4,121*	*479*	*101*
Loans, cemeteries	*5*	*1*	—
Debt	19,267	3,729	1,181
GRAND TOTAL	$219,915	$53,416	$23,967

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[1] Adapted from the Report on the Statistics of Municipal Finances—1926, Massachusetts Public Document No. 79.

Table A 8.—Total Expenditures of the Central State Government, 1910, 1915, 1920 and 1924.[1]

(Thousands of dollars)

	1910	1915	1920	1924[2]
General Government	$ 2,115	$ 3,325	$ 4,391	$ 4,446
Legislative	401	510	996	794
General Administration	1,150	2,081	2,472	2,463
Judicial	564	734	923	1,189
Education	1,789	3,071	4,727	6,448
General	1,116	1,657	2,787	3,572
Vocational—Agricultural	274	537	967	1,126
Vocational—Technical	308	710	683	1,340
Gifts, Grants and Trusts—Agricultural	71	86	110	115
Gifts, Grants and Trusts—Technical	20	81	281	295
Total Gifts, Grants and Trusts	*91*	*166*	391	*410*
Total Agricultural	*345*	*623*	*1,077*	*1,241*
Total Technical	*328*	*791*	*964*	*1,635*
Highways and Waterways	2,428	3,995	7,483	12,284
Highways	*2,008*	*2,910*	*5,479*	*10,496*
Highway Trust	....	....	*218*	*1,044*
Total Highways	2,008	2,910	5,697	11,540
Waterways	420	1,085	1,786	744
Charity	1,273	2,017	3,403	4,099
Mental Diseases	3,198	4,274	7,353	8,142
Corrections	1,907	1,868	3,017	2,906
Health	951	1,259	1,657	1,598
Public Safety	182	238	303	777
General	182	238	206	268
State Police	....	....	97	509
Labor	109	369	452	473
Conservation	435	542	437	712
General	2	3	4	14
Forestry	363	391	218	486
Fisheries and Game	70	148	215	212
Agriculture	155	368	267	393
General	52	102	118	135
Dairy and Animal Husbandry	103	266	149	258
Public Utilities	136	222	198	194
Banks and Insurance	137	231	340	452
Banking	55	119	208	301
Insurance	82	112	132	151
Military	1,810	2,041	6,456	1,739
Maintenance and Operation	735	1,112	1,581	823
Gratuities	....	5	3,509	270
Pensions and State Aid	1,028	878	1,327	603
Trust	47	46	39	43
Miscellaneous	26	165	174	47
Interest and Debt	2,442	3,353	5,957	3,366
Interest	1,286	1,817	2,838	1,459
Debt	424	819	1,619	1,191
Sinking Funds	732	717	1,500	716
Payments from Revenue	*1,710*	*2,636*	*4,457*	*2,650*
GRAND TOTAL	$19,093	$27,338	$46,716	$48,076

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[1] This analysis was made by a careful consideration of all available financial reports. The attempt here has been to classify State expenditures by purpose rather than by departments. The figures, therefore, will not coincide with the department total in many cases. Reports for the years 1910, 1915 and 1920 were placed on the same accounting basis as for 1924, and the same items have been included in each classification for each year.

[2] State expenditures have remained fairly constant since 1924.

Table A 9.—Receipts per Capita, for Cities and Towns, 1926.

Size of City or Town	Number of Cities or Towns	Receipts per Capita			*Per cent of Total Receipts*	
		From Taxes	From Gifts and Grants	Total	*From Taxes*	*From Gifts and Grants*
Towns						
Under 500	44	$37.64	$21.68	$64.04	*58.8*	*33.9*
500-1,000	39	36.65	12.58	54.74	*67.0*	*23.0*
1,000-1,500	40	43.43	6.01	55.64	*78.1*	*10.8*
1,500-2,000	34	42.22	4.90	52.95	*79.7*	*9.3*
2,000-2,500	20	39.02	4.81	50.30	*77.6*	*9.6*
2,500-3,000	19	51.35	2.19	61.42	*83.6*	*3.6*
3,000-4,000	28	39.53	.97	46.49	*85.0*	*2.1*
4,000-5,000	17	38.02	1.02	43.14	*88.1*	*2.4*
5,000-7,000	26	39.24	.43	47.44	*82.7*	*.9*
7,000-10,000	22	44.14	.40	58.21	*75.8*	*.7*
10,000-15,000	19	41.77	.73	51.16	*81.6*	*1.4*
Over 15,000	12	52.66	.33	63.71	*82.7*	*.5*
Cities						
Under 25,000	13	41.47	.56	53.74	*77.2*	*1.0*
25,000-50,000	11	44.48	.34	54.37	*81.8*	*.6*
50,000-75,000	5	52.12	.62	67.13	*77.6*	*.9*
75,000-100,000	2	39.65	.41	45.66	*86.8*	*.9*
100,000-150,000	6	51.30	.65	60.46	*84.8*	*1.1*
150,000-200,000	1	52.56	.11	64.78	*81.1*	*.2*
Over 200,000	1	77.69	.39	94.99	*81.8*	*.4*

Table A 10.—Principal Sources of Receipts for Governmental Purposes, 1926. *(Percentages)*

Source of Receipts	*Central State Gov't*	*Towns under 5,000*	*Towns over 5,000*	*Cities*
General property tax	23.31	76.40[1]	75.87[1]	76.25[1]
Corporation taxes	17.73	3.90	4.93	5.66
Departmental	15.25	3.22	3.07	3.17
Public service enterprises	....	4.89	12.20	9.01
Motor vehicle fees	25.76	....	....	....
Inheritance tax	12.58	....	....	....
Miscellaneous	5.37	11.59	3.93	5.91
Total	100.00	100.00	100.00	100.00

[1] Includes poll tax.

Table A 11.—Assessed Valuation, Property Taxes and Poll Taxes, 1910-1926.
(Thousands of dollars)

Year	ASSESSED VALUATION				TAXES			
	Real Estate	Land only	Personalty	Total	General Property	Real Estate	Poll	Total Local Tax
1910	$2,977,075	$1,429,131	$930,817	**$3,907,892**	$66,716	$51,307	$1,872	**$68,589**
1911	3,092,791	1,468,824	984,444	**4,077,235**	69,391	53,175	1,897	**71,289**
1912	3,217,917	1,528,817	1,067,450	**4,285,368**	73,181	55,504	1,930	**75,112**
1913	3,355,012	1,585,739	1,116,724	**4,471,736**	79,713	60,336	1,968	**81,682**
1914	3,468,351	1,620,056	1,176,463	**4,644,814**	85,970	64,706	2,012	**87,983**
1915	3,574,761	1,654,769	1,195,098	**4,769,860**	90,879	68,776	2,055	**92,936**
1916	3,686,483	1,687,488	1,275,754	**4,962,238**	93,683	70,355	2,087	**95,771**
1917	3,808,405	1,715,911	730,592	**4,538,998**	89,330	74,732	2,163	**91,495**
1918	3,885,495	1,735,151	853,481	**4,738,976**	99,691	81,617	2.108	**101,800**
1919	3,981,578	1,765,145	922,197	**4,903,775**	114,359	92,794	2,105	**116,465**
1920	4,370,729	1,867,016	983,357	**5,354,086**	137,353	111,963	5,048	**142,403**
1921	4,525,853	1,889,365	1,020,792	**5,546,646**	147,812	120,533	5,072	**152,885**
1922	4,706,612	1,950,180	1,008,765	**5,715,377**	157,129	129,114	5,771	**162,901**
1923	4,968,716	2,000,784	1,009,435	**5,978,152**	161,836	134,188	5,835	**167,673**
1924	5,251,977	2,055,894	1,048,682	**6,300,660**	174,597	145,245	2,395	**176,993**
1925	5,560,636	2,133,069	1,072,119	**6,632,755**	189,246	158,630	2,447	**191,694**
1926	5,839,811	2,192,853	1,065,226	**6,905,037**	209,560	177,648	2,452	**212,012**

PUBLICATION OF THIS DOCUMENT APPROVED BY THE

COMMISSION ON ADMINISTRATION AND FINANCE

3m-1-'30. No. 7634

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 257 December, 1929

The Cutaneous Vaccine for Fowl Pox

By Norman J. Pyle

Investigation of fowl pox at this Station has for its purpose the determination of an efficient preventive and curative treatment for the disease. This is of vital importance to the Massachusetts poultry industry because the disease causes serious loss by decreasing egg production during the season when eggs are highest priced.

The study of the cutaneous vaccine, as here reported, included investigations of its efficiency, its practical use and method of administration, its action on body weight, temperature, and early egg production, and the duration of immunity which followed its administration.

Requests for Bulletins should be addressed to the

AGRICULTURAL EXPERIMENT STATION

AMHERST, MASS.

THE CUTANEOUS VACCINE FOR FOWL POX

By Norman J. Pyle, Assistant Research Professor of Avian Pathology.

Cutaneous vaccination against fowl pox[1] (chicken pox, contagious epithelioma) has been given considerable attention during the last few years in this country and abroad. The work of De Blieck and Van Heelsbergen (1) is widely known and needs little reference here. Their vaccine, known as "Antidiphtherin", is described as "a thoroughly living vaccination material". Reports of similar investigations by Johnson (2), Pyle (3), Edgington and Broerman (4), and Sawyer (5) have been published. These writers concur in the conclusion that poultry can be fully protected against fowl pox by the administration of an unattenuated virus suspension or cutaneous vaccine to the scarified skin or denuded feather follicles.

The early work of the writer (3) dealt largely with the type of immunity that is conferred against fowl pox. A serological study of fowls which were immune to the disease, showed a low degree of specific antibody concentration in their sera. Attempts to produce a passive immunity were not successful. An efficient cutaneous vaccine was developed and a tentative method of standardizing it was suggested. Birds which were completely immune to both the natural infection and the experimental infection following cutaneous vaccination, were found to have no specific antibodies in their sera. Therefore, it was concluded that a cutaneous immunity was the chief protecting force against fowl pox. The work of Verge (6) is a practical demonstration of this type of immunity in relation to fowl pox, while that of Besredka (7) goes deeply into the theoretical explanation and application of the phenomenon.

The work herein reported considers additional information on the use and efficiency of this vaccine, its reaction on birds of various ages, its curative as well as its preventive effect, a modification in its virus content, the duration of immunity which it produces, and the action of the glycerol content of the diluent on the virus in the vaccine.

The Cutaneous Vaccine and Its Administration

The cutaneous vaccine as described and standardized by the writer (3), with the exception of one modification which will be mentioned later, was used in all the experiments described in this bulletin. It contained 200 mgm. of powdered pox virus suspended in 50 cc. of sterile 40 per cent glycerol-physiological saline solution. Phenol was not added to the vaccine and the preparation was not attenuated by heat. The virus varied in age from six weeks to seven months and it consistently produced definite lesions of fowl pox in from four to seven days, or sooner, after its inoculation on the combs of birds of the same age as those which were to be vaccinated.

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[1] Fowl pox is manifested by wartlike scabs on the unfeathered portions of the head and the accumulation of cheesy material, pseudo-membranes, or ''cankers'' on the membranes of the mouth, larynx, and in the cleft palate. The latter group of symptoms is characteristic of the internal form of fowl pox or avian diphtheria ("canker"). The two forms of the disease are due to the same cause, a filtrable virus. When there is a muco-purulent discharge from the eyes and nose, or these organs and the infraorbital sinuses are distended with cheesy exudates, the disturbance is known as roup. Roup may occur in Massachusetts concurrently with fowl pox or it may be seen alone. It is generally accepted that its specific cause is as yet unknown, but there is evidence to the effect that the filtrable virus of fowl pox is at least implicated. The eyes may be involved in avian diphtheria, and if they are, it is difficult to differentiate it from roup.

The site selected for vaccination was on the outside of either leg just above the "hock" joint (tibio-femoral articulation). An area of approximately one square inch was denuded of feathers at this point. If the feathers were plucked from a point higher on the leg there was danger of tearing the skin. The vaccine was then rubbed into the open follicles with a small camel's hair brush which had been cut down to about one-fourth of an inch from its quill insertion, in order to give it a necessary stiffness. Not less than three and not more than seven to ten follicles were vaccinated. The immunity which followed a "take" involving but a few follicles appeared to be as complete as when more follicles were concerned. Very little of the vaccine was used, it being the purpose to have the vaccinated area as dry as possible when the bird was released.

In denuding the area it was found preferable to pull the feathers in a direction parallel to their insertion in the follicles and not at right angles to this direction. In other words, the feathers should be pulled downward and not upward toward the back of the bird. This prevents hemorrhage from the small blood vessels at the base of the dermic papillae. The suffusion of blood into the follicles had a tendency to flush out or prevent the deposition and retention of vaccine in the open follicles. The feathers are usually pulled in the reverse direction because of its ease as compared to the preferred method.

In the earlier experiments (3) a cotton swab attached to a wooden applicator was used to brush the vaccine into the open follicles. It was very satisfactory, but had to be replaced after having been used on from 15 to 25 birds. When the camel's hair brush was suggested by Johnson (2) it was adopted and has been used since almost exclusively. However, the ordinary brush must be reenforced before being used. The quill of the brush is softened by soaking it in water for a few minutes and a small, tapering glass rod or piece of glass tubing is forced down into the quill without splitting it until it comes in contact with the hairs of the brush. When the quill hardens, the rod or tubing will be held firmly in place and prevent the hairs of the brush from pushing up into the quill when being used. A brush so reenforced can be used on several hundred birds. The brushes are kept in 2.5 per cent phenol when not in use and just before using are washed in sterile physiological saline solution.

In the routine vaccination of a number of birds it was found desirable to have plenty of vaccine on hand. Two or three cubic centimeters were poured from the stock container (50 cc. vaccine bottle) into a sterile Stender dish. Any similar piece of glassware may be used. This quantity was sufficient to vaccinate approximately 100 birds, but it was discarded after having been used on from 35 to 50 birds because it became too adulterated with epithelial debris and an exudate of mucous consistency from the follicles and the inferior umbilicus of the feather quills. The Stender dish and its contents were discarded into a beaker of disinfectant. A second sterile Stender dish and 2 or 3 cc. of vaccine were taken, and so on until all birds were vaccinated. A number of brushes were kept at hand and used alternately, with each group of 35 to 50 birds.

About the third or fourth day after vaccination the majority of the follicles showed a slight swelling which gradually became more pronounced, until on the eighth to tenth day after vaccination, individual follicular scabs began to develop which later became coalescent in most of the cases. The scabs began to drop off on or about the eighteenth to twentieth day after vaccination, and were usually entirely gone by the twenty-eighth to thirty-first day. At this time the immunity was complete.

The cutaneous vaccine should not be used in a flock unless the disease was prevalent in former seasons and it is reasonably certain that it will appear again. All the young stock on the premises should be vaccinated. The cutaneous vaccine is unattenuated and, therefore, will serve to introduce the infection to unvaccinated, susceptible birds by contamination of litter, feed, water, etc. Yearlings or older birds may or may not be treated. As a rule, they have developed a resistance against the disease during a previous outbreak.

Preventive Flock Vaccination and Its Effect on Early Egg Production

During the last four years opportunity has been given to study fowl pox, avian diphtheria, roup, and colds as they occurred in the spontaneous or natural form in the two flocks maintained at this institution. These outbreaks have occurred annually during this period at a time when egg production was at its peak. Pens would drop in total egg production to an alarming degree. This also occurred in other flocks throughout the State. The economic situation was serious. An imposing annual loss and disarrangement of breeding programs were necessarily anticipated from year to year. Experimental vaccines, bacterins (8), and one commercial vaccine had been used in several of these flocks with some success. By late summer of 1928 such confidence had been placed in the cutaneous vaccine that it was decided to use it on the two important flocks above mentioned.

Flock 1.

This flock, maintained by the College poultry department for teaching, breeding, and commercial purposes, contained, aside from the older stock, 1511 birds which were hatched during the late winter and spring of 1928. They consisted for the most part of Rhode Island Reds and one or two pens each of White Leghorns and Barred Plymouth Rocks. They were all trapnested and some were pedigreed. They were cutaneously vaccinated as they were brought in from the range to the laying houses. The first lot of the 1511 pullets and cockerels was housed on September 5; the last lot on October 11. The yearlings and older birds were not vaccinated because they had either gone through the disease during the previous year or, in the opinion of the writer, had developed enough resistance to withstand a natural outbreak of the infection.

The birds were first bled for the detection of pullorum disease (*Salmonella pullorum* infection) by means of the agglutination test as they were taken from the crates. Next they were handed to the operator who vaccinated them. After this they were placed in the laying pens. A varying number of follicles was vaccinated, never less than three or more than ten. This was done for the purpose of comparing the number of follicles implicated in the vaccine reaction with the effect on the bird.

All the birds were examined periodically after the treatment. In some of the more crowded pens small diphtheritic patches, rarely larger than the head of a pin, developed on the mucosa of the mouth in about 5 to 10 per cent of the birds. In some pens 2 to 3 per cent of the birds showed small pox nodules on the comb and eyelids. These lesions developed about four or five days after the treatment and disappeared within the next seven days. They were regarded as of negligible importance. These lesions developed within the usual incubation period of the disease and were permitted to do so because of the fact that cutaneous immunity in fowl pox, as demonstrated in our previous work (3), does not begin to develop definitely until the twentieth day after vaccination, becoming complete on the twenty-ninth to thirty-first day.

With the exception of the slight lesion cases which developed soon after the vaccination, there has not been one case of fowl pox or avian diphtheria in this flock since the treatment. Furthermore, colds and roup have been practically absent. This latter fact is interesting, but by no means conclusive evidence that cutaneous vaccination protects against colds and roup as well as fowl pox. With outbreaks of fowl pox occurring on this plant annually for the previous four years, one would expect it to recur the fifth year.

Two or three months after this flock was vaccinated it was accidentally subjected to natural infection. A group of 60 White Leghorn cockerels had been quartered in a fenced-in enclosure on the premises. These birds were not vaccinated because they were a reserve group from which birds were to be taken for indicatory experiments. The natural infection appeared in these birds, and some escaped through the fence, exposing the vaccinated birds to the infection. Lesions of the disease did not appear in the vaccinated birds as a result of this exposure to the natural infection.

It was impossible to control the work properly by leaving unvaccinated birds in the various pens. The flock is an important one because of the varied uses made of it. It must be kept in the best of condition, and it was feared that unvaccinated birds would come down with the infection later on and seriously interfere with the flock program.

A careful analysis was made of the egg production of all vaccinated birds. Many of the pullets were laying at the time that they were vaccinated; some pens laying as high as 10 per cent. Several feeding experiments were being carried on at the same time and the birds were being constantly handled for student instruction. Production records of unvaccinated controls were not available. Therefore, a complete and accurate summary of the effect of vaccination on this early egg production could not be made. The results, however, to some degree were comparable to that of flock 2.

Flock 2.

This flock is maintained by the Agricultural Experiment Station for its work in genetics. It had been affected by annual outbreaks of pox, diphtheria, colds, and roup and had been treated similarly to flock 1. In the late summer of 1928 there were 1202 birds on this plant, 905 of which were Rhode Island Red pullets and cockerels. The remainder consisted of older stock. The young birds were vaccinated cutaneously soon after they were transferred from the range to the laying houses. As in flock 1, blood samples were collected for the detection of pullorum disease just prior to vaccinating the birds. The older birds, likewise, were not treated. No unvaccinated young birds were left as controls because of reasons similar to those mentioned in connection with flock 1. The vaccinated birds were divided into groups as follows:

House 1—263 pullets, housed September 10, vaccinated September 12.
House 2—249 pullets, housed September 17, vaccinated September 20.
House 3—244 pullets, housed September 24, vaccinated September 26.
South long house—149 cockerels, housed on various dates, vaccinated September 27.

Unimportant lesions, similar to those seen in flock 1, appeared shortly after the vaccination and disappeared rapidly. All birds were free of fowl pox and diphtheria throughout the year. Likewise, colds and roup were entirely absent. There was no mortality whatever that could be traced to the results of the vaccination.

All birds were trapnested, and a careful study was made of their egg records prior and subsequent to the vaccination in order to determine what effect, if any, the vaccination might have on their early egg production. The results of this study are shown in Chart 1. As stated, there were no available control birds in this flock. For this purpose the early production records of house 1 for 1926 were taken and are marked "Control" in the

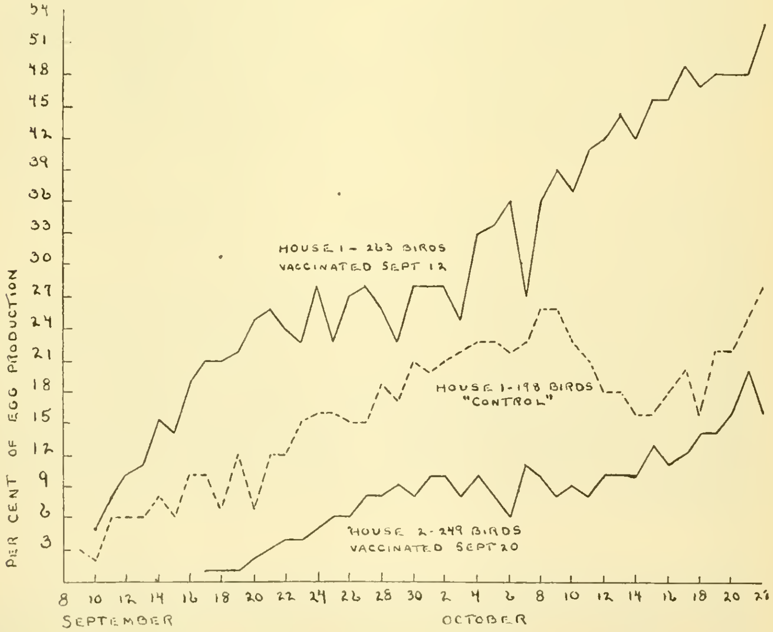

CHART 1. The Effect of Cutaneous Vaccination on Early Egg Production.

chart. Those of 1927 were unsuitable because the use of a commercial vaccine had caused a pronounced decrease in production during this early period. The control curve shows a marked decrease in production beginning on October 9. This was due to a natural outbreak of the infection which occurred at that time. A curve for house 3 is not shown on the graph because the birds in this pen were of a late hatch and had not come into production at the time this study was made.

Interpretation.—The birds in house 1 were producing 5 per cent on September 10, the day they were housed. They were vaccinated on September 12. On September 22 the gradual increase in percentage of early egg production was slightly retarded, wavering somewhat until October 7 when it again began to increase. The birds in house 2 were housed on September 17 and vaccinated on September 20. In this case the curve wavered between September 29 and October 11. The effect of the vaccination on the early egg production was similar for the two houses.

This slight retardation in the increase of early egg production corresponds to the decrease in egg production following vaccination in pullets more advanced in production, which was shown in our previous report (3). It began on the eighth day after vaccination and had reached its lowest point on the twenty-first day after vaccination. This slight effect on the increase in early egg production should not be considered of any great importance. Any preventive treatment given to the domestic fowl will have a similar effect. The benefits derived from this method of vaccination warrant its use. The results of this experiment indicate that it is safe to vaccinate birds cutaneously against fowl pox as they are transferred from the range to laying houses, even though they are in the early stages of egg production at the time.

The birds used in the above experiments were in good physical condition and free of any infectious, dietary, or marked parasitic disturbance. It is possible that if their health had been otherwise there might have been some adverse effect following the vaccination. All the investigators who have worked with this vaccine mention its danger when administered to unhealthy flocks.

The Effect of Cutaneous Vaccination on Body Weight and Temperature

The following experiments were designed to determine what change, if any, would take place in body weight and temperature of birds of various ages following cutaneous vaccination. The results would indicate at what age it is safe to vaccinate a flock in this manner. Our previous work had been carried out on birds of approximately five and six months of age or older. It is undesirable to vaccinate after birds are well into egg production because of the marked decrease that follows. It was demonstrated in the previous experiment that early production was not affected to any great degree, but the results may not always be favorable, especially if the vaccine is administered improperly or carelessly by one who has not had previous experience in using it. Therefore, it seems desirable to vaccinate on range where the birds are not subjected to the crowded conditions of the laying houses, where the chance of contact infection following vaccination is greatly lessened, and the contamination of the houses with the virulent vaccination material is avoided.

TABLE 1.—Summary of Body Weight and Rectal Temperature Readings Taken Before and After Cutaneous Vaccination.

EXPERIMENT 1—White Leghorn Cockerels—age 210 days

Treatment	Bird Number	Preliminary stage, 39 days				Stage of infection, 25 days				Stage of recovery, 12 days			
		Temperature Min.	Temperature Max.	Weight Min.	Weight Max.	Temperature Min.	Temperature Max.	Weight Min.	Weight Max.	Temperature Min.	Temperature Max.	Weight Min.	Weight Max.
		°F.	°F.	*grams*	*grams*	°F.	°F.	*grams*	*grams*	°F.	°F.	*grams*	*grams*
Controls not vaccinated	1	106.8	109.0	1560	1990	107.4	108.6	1890	2030	107.5	108.0	1980	2110
	2	107.1	108.5	1150	1830	107.7	109.2	1810	2060	107.8	108.1	2070	2150
	3	107.0	109.0	1480	1790	107.3	109.2	1800	1840	107.8	108.4	1750	1810
	4	107.3	109.5	1510	1710	107.0	108.8	1690	1770	107.9	108.3	1740	1800
Vaccinated 200 mgm. vaccine	5	106.8	108.5	1680	2080	107.1	108.9	1960	2230	107.3	108.0	2210	2310
	6	107.0	108.4	1360	1860	107.2	109.3	1780	1960	107.4	108.1	1950	2140
	7	107.3	108.8	1470	1860	107.7	108.7	1800	1970	107.7	108.3	1910	2100
	8	107.2	108.6	1310	1610	107.3	109.2	1620	1700	107.7	108.1	1690	1800
	9	107.3	108.7	1940	2280	107.6	109.4	2260	2390	107.7	108.5	2320	2430
	10	107.1	109.0	1660	1850	107.6	108.8	1840	2020	108.0	108.6	2020	2070

EXPERIMENT 2—R. I. R. Pullets and Cockerels—age 80 days

Treatment	Bird Number	Preliminary stage, 9 days				Stage of infection, 26 days				Stage of recovery, 3 days			
		Temperature		Weight		Temperature		Weight		Temperature		Weight	
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
		°F.	*°F.*	*grams*	*grams*	*°F.*	*°F.*	*grams*	*grams*	*°F.*	*°F.*	*grams*	*grams*
Controls not vaccinated	2455	107.7	108.1	1200	1330	107.1	108.5	1350	1540	107.5	107.7	1540	1580
	2456	106.8	107.5	1100	1250	106.8	108.0	1250	1600	107.1	107.4	1620	1660
	2457	107.2	108.4	970	1130	107.1	108.4	1170	1570	107.4	107.9	1620	1670
	2458	107.5	108.0	1060	1250	107.2	108.6	1250	1520	107.7	107.8	1520	1560
	2459	107.5	108.3	1030	1200	107.2	108.2	1180	1320	106.8	108.1	1180	1290
	2460	106.9	107.8	990	1150	107.0	108.6	1130	1480	106.8	107.1	1340	1480
Vaccinated commercial vaccine	2461	107.1	107.7	1130	1250	107.1	107.8	1270	1830	106.8	107.1	1830	1900
	2462	107.0	107.5	1140	1330	107.3	108.0	1300	1770	107.6	107.8	1770	1830
	2463	107.3	107.6	1010	1180	107.3	107.9	1190	1680	107.1	107.6	1680	1720
	2464	107.2	107.8	1170	1330	107.1	108.0	1200	1540	107.1	107.3	1560	1590
	2465	107.9	108.4	1140	1270	106.0	108.9	1260	1330	111—destroyed-		enteritis	
	2466	107.0	107.7	1140	1300	107.2	108.0	1200	1600	106.7	107.3	1600	1660
	2467	107.0	107.4	1050	1230	106.6	107.5	1240	1640	107.6	107.7	1710	1750
	2468	106.8	107.6	940	1100	106.7	108.2	910	1320	107.1	107.2	1370	1420
	2469	107.9	108.4	870	1020	107.7	108.4	1020	1300	107.9	107.9	1330	1340
Vaccinated 200 mgm. vaccine	2470	106.8	107.6	1050	1130	107.3	108.4	1130	1390	107.3	107.7	1430	1470
	2471	107.5	108.0	1060	1240	107.2	108.6	1250	1630	107.5	107.6	1690	1700
	2472	107.4	108.1	1170	1360	107.4	108.2	1360	1670	107.0	107.4	1730	1750
	2473	107.1	108.0	1120	1270	107.3	108.5	1320	1700	107.6	107.7	1770	1820
	2474	107.5	108.1	1190	1330	107.4	108.6	1360	1520	107.4	107.6	1570	1620
	2475	107.1	108.4	1140	1340	106.9	108.7	1310	1440	106.9	107.2	1490	1530
	2476	106.6	108.1	1070	Dead-	cannibalism							
	2477	107.4	107.8	1220	1350	107.3	108.3	1360	1750	107.5	107.8	1760	1810
	2478	107.4	108.1	1170	1330	106.8	108.6	1260	1520	107.0	107.2	1520	1590
Vaccinated 100 mgm. vaccine	2479	107.0	107.8	1010	1220	106.8	107.8	1240	1530	107.0	107.8	1580	1640
	2480	107.4	107.6	950	1110	107.0	108.4	1130	1540	107.3	108.4	1460	1530
	2481	107.5	108.1	850	1010	107.4	108.8	950	1330	107.8	108.4	1350	1370
	2482	107.2	107.6	970	1160	107.0	108.0	1170	1710	107.1	107.2	1760	1810
	2483	107.0	107.8	1150	1320	106.7	108.1	1320	1630	107.5	107.5	1600	1640
	2484	107.5	108.4	1010	1170	107.1	108.1	1190	1600	107.2	107.2	1650	1710

TABLE 1.—Summary of Body Weight and Rectal Temperature Readings Taken Before and After Cutaneous Vaccination.—*Concluded.*

EXPERIMENT 3—R. I. R. Pullets and Cockerels—age 68 days

Treatment	Bird Number	Preliminary stage, 7 days				Stage of infection, 33 days				Stage of recovery, 4 days			
		Temperature		Weight		Temperature		Weight		Temperature		Weight	
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
		°F.	°F.	*grams*	*grams*	°F.	°F.	*grams*	*grams*	°F.	°F.	*grams*	*grams*
Controls not vaccinated	2439	107.0	107.8	415	562	107.3	108.1	590	1344	107.8	107.8	1340	1369
	2440	107.0	108.0	351	448	107.6	108.2	487	1093	107.6	107.9	1069	1095
	Gray band	107.5	108.6	386	493	Dead—cannibalism							
	2441	107.1	108.1	518	667	107.0	108.1	696	1399	107.0	107.6	1428	1484
	2442	107.1	108.1	436	589	107.1	108.0	620	1445	107.5	107.6	1454	1498
	2443	107.2	107.3	479	634	106.9	108.0	671	1353	106.9	108.0	1393	1452
Vaccinated 300 mgm. vaccine	2444	107.6	108.2	403	509	107.3	108.9	532	1093	107.6	108.1	1132	1157
	2445	107.2	108.1	336	443	107.7	108.9	467	964	107.7	108.3	990	1022
	2446	107.3	108.2	444	540	107.4	108.6	552	1122	107.4	108.0	1148	1187
	2447	107.4	108.0	447	563	107.5	108.4	594	1235	107.8	107.9	1289	1337
Vaccinated 200 mgm. vaccine	2448	107.3	108.2	474	590	107.3	108.9	606	1003	107.6	108.1	1039	1088
	2449	107.6	108.3	516	620	107.2	108.6	597	977	107.6	107.9	1022	1045
	2450	107.5	108.1	409	495	107.4	108.4	496	951	107.4	108.1	980	1020
	2451	107.3	108.1	539	641	107.2	108.6	642	1209	108.1	108.4	1229	1283
Vaccinated 100 mgm. vaccine	2452	107.7	108.3	365	436	107.2	108.6	449	960	107.7	107.8	988	1020
	Yellow band	107.6	108.2	427	515	Dead—cannibalism							
	2453	107.6	108.5	417	505	107.1	108.2	523	1023	107.4	107.6	1044	1081
	2454	107.7	108.4	261	351	107.3	108.6	366	895	107.4	107.9	918	951

Weight and rectal temperatures were recorded daily between 10 A. M. and 12 M. during the extent of the three experiments described. For the purpose of comparison the readings of the three experiments are grouped together in Table 1. The minimum and maximum temperatures and weights are recorded for each of the three stages of each experiment. The preliminary stage represents the period during which readings were taken in order to determine the normal rectal temperature and increase in body weight. It covers the time from the beginning of the experiments to the day of vaccination. The stage of infection is that period of time from the day on which the birds were vaccinated to the day on which the scabs had entirely disappeared from the vaccinated area. The stage of recovery is that period of time during which the birds would naturally return to normal if there were a deviation from the normal during the stage of infection.

All birds in these experiments were confined to individual experimental cages. The birds in experiment 1 were hopper-fed whole yellow corn and a commercial laying mash. This ration was supplemented with 1 per cent cod liver oil, and cabbage was fed twice weekly. Those in experiment 2 were fed intermediate scratch feed and a growing mash in hoppers, supplemented with 1 per cent cod liver oil. In experiment 3 the birds were first fed a mixture of two-thirds growing mash and one-third fine scratch feed with 1 per cent cod liver oil until 100 days old, and later growing mash and intermediate scratch feed ad libitum in separate hoppers, 1 per cent cod liver oil being mixed with the mash.

Group 1.

Ten White Leghorn cockerels, approximately 210 days of age, were used in this experiment. Six of the birds were vaccinated cutaneously with the standard vaccine containing 200 mgm. of virus in 50 cc. of 40 per cent glycerol-physiological saline solution. The remaining four birds were used as unvaccinated controls. Forty days after vaccination the combs of the entire group were scarified and inoculated with a heavy suspension of fowl pox virus in order to determine if immunity against the disease had developed. No lesions appeared as a result of the inoculation in the vaccinated birds. The unvaccinated controls showed from a moderate to a severe type of infection as a result of the inoculation. The vaccination had caused the development of a complete protection (cutaneous immunity) against the disease.

Group 2.

Thirty Rhode Island Red pullets and cockerels of the same strain and hatch were used in this experiment, twenty-four being vaccinated and six left unvaccinated as controls. They were 80 days old on the day they were vaccinated. Three different vaccines were used in this experiment; one, a widely distributed commercial cutaneous vaccine; the second, the standard 200 mgm. vaccine; and the third, a vaccine identically the same as the standard vaccine except that it contained but one-half as much virus, or 100 mgm.

When vaccinating birds so young, it was necessary to exercise unusual precautions. In many cases the feather follicles were so small that it was difficult to brush the vaccine into them. Frequently it was necessary to vaccinate slightly higher up on the leg than usual, where the follicles were somewhat more mature and open to a greater extent.

In connection with the tentative standardization of the cutaneous vaccine (3), it was noted that when less than 200 mgm. of virus were used in the vaccine, it failed to produce local reactions ("takes") in all trials. When more than this amount of virus was used a more pronounced generalized reaction was the result. These conclusions were based on the results obtained after working with birds from five to six months of age or older. In this and the following experiment the 100 mgm. vaccine produced clear-cut "takes" in every instance. The birds used in these experiments were younger and had not developed the degree of natural cutaneous resistance to the vaccine that older birds had developed.

Group 3.

Eighteen Rhode Island Red pullets of the same hatch and strain were used, and six were left unvaccinated as controls. They were 68 days old on the day of vaccination. Here again three vaccines were used, containing 300, 200 (standard), and 100 mgm. of virus, respectively. The immaturity of the follicles in these birds necessitated more careful vaccination than in the previous experiment.

Interpretation.—The normal temperature of the domestic fowl varies considerably. The records in Table 1 show a slightly higher normal range of temperature in the White Leghorn cockerels than in the Rhode Island Red pullets and cockerels. This perhaps can be attributed to the greater activity of the former breed. They were older than the Rhode Island Reds, but this should not have influenced the temperature in this case.

A careful analysis of the temperatures taken during the stage of infection in all the experiments shows a slight increase over those taken during the preliminary stage. The increase averages less than 1° F. and is but slightly more noticeable in the vaccinated than in the unvaccinated control groups. The average temperature of both groups in all experiments during the stage of recovery is lower than that recorded during the stage of infection.

It is difficult to draw any definite conclusion from these data on rectal temperatures. The slight increase in temperature during the stage of infection was of little importance.

Table 2 shows the minimum, maximum, and average gain in weight attained by each group, as a whole, during the stage of infection in the three experiments. It presents the weight records of Table 1 in a form suitable for more ready interpretation. The figures for each group were obtained by determining the difference between the minimum and maximum weight for each bird during the stage of infection in the three experiments. The smallest of these differences is the group minimum and the largest the group maximum. The sum of these differences for each bird, divided by the number of birds represents the average gain of the group.

Table 2.—Total and Daily Gain in Weight During the Stage of Infection Following Cutaneous Vaccination. (Summarized from Table 1.)

Treatment	Length of stage, days	Total gain in weight, grams			Daily gain in weight, grams		
		Min.	Max.	Aver.	Min.	Max.	Aver.
EXPERIMENT 1—White Leghorn Cockerels—age 210 days							
Controls	25	40	250	**128**	1.6	10.0	**5.1**
Vaccinated (200 mgm.)	25	80	270	**168**	3.2	10.8	**6.7**
EXPERIMENT 2—R. I. R. Pullets and Cockerels—age 80 days							
Controls	26	140	400	**283**	5.4	15.4	**10.9**
Vaccinated (commercial)	26	70	560	**380**	2.7	21.5	**14.6**
Vaccinated (200 mgm.)	26	130	390	**283**	5.0	15.0	**10.9**
Vaccinated (100 mgm.)	26	290	540	**390**	11.2	20.8	**15.0**
EXPERIMENT 3—R. I. R. Pullets and Cockerels—age 68 days							
Controls	33	606	825	**743**	18.4	25.0	**22.5**
Vaccinated (300 mgm.)	33	497	641	**567**	15.1	19.4	**17.2**
Vaccinated (200 mgm.)	33	380	567	**449**	11.5	17.2	**13.6**
Vaccinated (100 mgm.)	33	500	529	**513**	15.1	16.0	**15.5**

Interpretation.—In forming conclusions from these data it is necessary to bear in mind that individual birds vary considerably in tendencies governing increase in weight. This is influenced by several factors; chiefly, by the relative amount and the quality of the feed consumed by the individual. The variation in initial weight is another factor which must be considered when interpreting these figures. This influenced the average gain in weight of a group, as a whole, to some extent even though each group was carefully selected as to comparable weight.

In general these data indicate that the vaccine does not cause a retardation in the gain in weight following its administration to birds 80 days of age or older. They do indicate, however, that there is a slight retardation in gain in weight following its administration to birds 68 days of age. This slight retardation in gain in weight was relatively unimportant for the same reasons mentioned in connection with the slight retardation in early egg production. Recovery was rapid.

The 100 mgm. vaccine produced a follicular reaction comparable to that of the other vaccines and, therefore, its use appears to be indicated on birds of an age comparable to those in experiments 2 and 3. It contains one-half as much virus as the standard vaccine, which offsets to some degree the danger of spreading the infection and contaminating the premises.

The Use of the Cutaneous Vaccine in a Flock Infected with Fowl Pox

Late in September, 1928, attention was called to a small flock of Rhode Island Reds that was affected with fowl pox to a slight degree. It was decided to vaccinate cutaneously all birds in the flock in order to stay the spread of the infection if possible. The flock was located within walking distance of the College, and periodic personal observations of the results of the vaccination could be made. All the birds, confined in three separate units, were vaccinated and observations made of the results as follows:

Unit 1.

According to information received from the owner, the infection had started in this small unit, consisting of a pen of 17 hens and 1 cock. Fowl pox had never been present on the premises. Its source of introduction into the flock could not be traced. Eight of these birds showed typical lesions of fowl pox of a severe form, which apparently had been present for about one week. All 18 birds were vaccinated cutaneously with the standard vaccine on September 26. Those birds showing lesions of pox demonstrated no follicular reaction whatever, while those not showing lesions responded to the vaccination with a slight follicular swelling, which was not followed by scab formation. This swelling appeared on the third day but was not present on the eighth day after vaccination. The infection in this pen entirely disappeared by October 23.

Unit 2.

This unit consisted of 125 pullets confined to an open yard about 75 feet distant from unit 1. These birds were vaccinated cutaneously on September 26, at which time they were moved from the yard to a laying house, closely adjoining unit 1. At the time of vaccination all birds were closely examined and three were found with slight, immature lesions of pox. It was evident that they had but recently become infected. About 90 per cent of the birds showed a slight follicular swelling in three days and a more pronounced swelling seven days after vaccination. On the thirteenth day the swellings were most prominent, and the first evidence of follicular scab development was noticed. No additional infection developed in this pen, and on October 23 the birds were well into production.

Approximately 10 per cent of these birds, including the three infected ones, failed to show any follicular reaction following vaccination. There was little probability that they had acquired immunity through a previous, unnoticed infection. They might have been non-susceptible or naturally immune to the disease. However, it appeared probable that these birds were fairly well advanced in the stage of incubation at the time they were vaccinated and sufficient cutaneous resistance had developed to prevent the vaccine from "taking". But in such cases one would expect to see a few minor pox lesions develop.

Similar results were obtained later in the year. White Leghorn cockerels were obtained for experimental purposes from a flock in which several cases of pox had existed. It was known that these birds had been in contact with the infected ones but had never shown lesions of the disease. When cutaneously vaccinated they failed to react with the development of swollen follicles and follicular scabs. The explanation of these results requires further investigation.

Unit 3.

This group consisted of 22 cockerels confined in a small house and large run adjacent to units 1 and 2. Upon examination five of the birds showed moderately severe pox lesions. They were vaccinated cutaneously on September 26. The vaccine did not "take" on the infected birds. The others showed the typical follicular reactions which appeared in units 1 and 2. No additional infection appeared in this unit.

Interpretation of Results.—Since it was impossible to use controls in this flock no conclusions can be drawn from the results. In carrying out the work it was hoped that some indication of the efficiency of the cutaneous vaccine, when used in this way, could be obtained. The results appear to indicate that cutaneous vaccination prevented further spread of the infection, and that the vaccination should be used immediately after the appearance of the natural infection in a flock.

The Duration of Cutaneous Immunity Against Fowl Pox

It has been definitely established that after recovery from an attack of fowl pox, either spontaneous in nature or artificially induced, a bird is immune to subsequent attacks for an indefinite period of time. Few and exceptional cases have occurred where birds have succumbed to a second attack of the disease. This acquired immunity is of long duration and in the majority of cases probably lasts throughout the remainder of life.

Cutaneous vaccination results in the development of a complete immunity in those cases, where the treatment is followed by the typical follicular swelling and scab formation. This has been repeatedly demonstrated by all investigators who have worked with this problem. This cutaneous immunity is apparently, also, of long duration. Sawyer (5) states that the birds are protected for at least two years and probably during life. Edgington and Broerman (4) report that, when young fowls are vaccinated during the summer or fall, they will be protected against fowl pox during the following winter and spring. Johnson (2) found the duration of immunity to be slightly less than 11 months, at least.

Early in November, 1927, a group of 100 trapnested, pedigreed Rhode Island Red pullets was vaccinated cutaneously at the College poultry plant of this institution. The report of that work is found in a previous bulletin (3). No opportunity was afforded to check the immunity produced in these birds by virus inoculation of the comb until they had completed their pullet year. The results of the check immunity tests on birds from this group are contained in Table 3.

For the complement-fixation studies in relation to cutaneous immunity (3) several Rhode Island Red cockerels had been vaccinated cutaneously during December, 1927, and January, 1928. Representative members of this group were found to be completely immune to fowl pox after check inoculation on the comb with a virulent virus suspension. The remainder were bled periodically for serologic tests and thereafter held over for the duration of immunity tests recorded in Table 3.

The unvaccinated controls used in this experiment were of the same age and breed as those vaccinated. They had never been subjected to the infection. All birds used in this experiment were kept in individual experimental cages and quarantined from any source of contamination with fowl pox infection.

TABLE 3.—Duration of Cutaneous Immunity Against Fowl Pox.
(Rhode Island Reds.)

Bird number	*Previous treatment*	*Date of vaccination*	*Date of inoculation*	*Results of inoculation—Lesions*	*Duration of immunity—Days*
Male 70	Unvaccinated		5-28-28	Severe	
Male no band	Unvaccinated		5-28-28	Severe	
Male V 83	Vaccinated	12-19-27	5-28-28	None	161
Male no band	Vaccinated	12-19-27	5-28-28	None	161
Male 63	Unvaccinated		6-5-28	Moderate	
Female 6484	Vaccinated	11-3-27	6-5-28	None	215
Female 6546	Vaccinated	11-3-27	6-5-28	None	215
Male 104	Unvaccinated		8-11-28	Moderate	
Male V 81	Vaccinated	12-22-27	8-11-28	None	233
Male V 82	Vaccinated	12-27-27	8-11-28	None	228
Female 6469	Vaccinated	11-3-27	8-11-28	None	282
Male no band	Unvaccinated		9-8-28	Severe	
Male no band	Unvaccinated		9-8-28	Severe	
Male V 86	Vaccinated	11-3-27	9-8-28	None	249
Male V 87	Vaccinated	1-12-28	9-8-28	None	240
Female 6480	Vaccinated	11-3-27	9-8-28	None	310
Female 6496	Vaccinated	11-3-27	9-8-28	None	310
Female 6502	Vaccinated	11-3-27	9-8-28	None	310
Female 6507	Vaccinated	11-3-27	9-8-28	None	310
Male no band	Unvaccinated		11-9-28	Moderate	
Male V 84	Vaccinated	12-22-27	11-9-28	None	322
Male V 85	Vaccinated	12-28-27	11-9-28	None	322
Female 6531	Vaccinated	11-3-27	11-9-28	None	371
Female 6570	Vaccinated	11-3-27	11-9-28	None	371

Interpretation.—To determine duration of immunity, inoculations with virulent virus were made on the combs of cutaneously vaccinated birds, on five different dates from May 28 to November 9, 1928. At each of these tests one or two unvaccinated birds were inoculated to serve as checks on the virulence of the virus used. The data show that all control birds developed a moderate to severe comb infection following the inoculation with the virulent virus. Without exception lesions were absent in the cutaneously vaccinated birds.

The results indicate that Rhode Island Reds, when cutaneously vaccinated early in their pullet and cockerel year, are completely immune to subsequent fowl pox infection for at least 371 days after vaccination, except for a period of 29 to 31 days immediately after the treatment, during which the immunity is developing. Additional birds were not available for immunity tests beyond this period of time. It is probable that the duration of immunity exceeds 371 days.

The Action of the Glycerol in the Diluent on the Virus Content of the Cutaneous Vaccine

It was shown in a previous report (3) "that when the cutaneous vaccine is 25 days or less in age at the time it is administered, it produces a complete immunity. When older it does not confer absolute protection against the experimental infection". It was suggested that this might have been due to an actual aging of the virus, the action of the glycerol upon it, or some other unsuspected factor. Beach (9) in experimenting with his subcutaneously administered lesion tissue vaccine, found that there was a change in the virus contained in the vaccine as a result of aging. Older vaccines did not produce as extensive and severe lesions as did the younger vaccines, when tested for their virulence. However, the lesions produced by the older vaccines showed a persistency and prominence comparable to those produced by the younger vaccines. Apparently the only differences between the lesions produced by the two groups of vaccines were their extensiveness and severity. Beach was inclined to believe that this change "in the virus content as a result of aging was more probably a decrease in amount due to the death of part of the virus than to a decrease in virulence".

The results obtained by the writer (3) were similar to some degree to those just described. The standard vaccine, administered at intervals of 6, 11, 16, 19, and 25 days after manufacture, produced pox eruptions (follicular swellings and scab formation) all in comparatively the same period of time. The follicular reaction resulting from the vaccine administered on the twenty-fifth day was just as severe and prominent as that administered on the sixth day. When the vaccine was administered on the thirty-first, fortieth, and forty-sixth day after manufacture a follicular swelling developed, but not the usual scab formation. It was evident that the standard vaccine became attenuated after 25 days of aging.

The following experiment was designed to determine whether the glycerol might be the cause of this attenuation. Glycerol was used in Beach's vaccine and probably was the cause of the evident "death of part of the virus". It was also borne in mind that the results of such an experiment might indicate some method by which the tentative method of standardizing the cutaneous vaccine (3) could be improved upon.

The action of the glycerol on the virus content of the vaccine necessarily had to be approached in an indirect manner. It has been shown that powdered fowl pox scabs contain, in addition to a filtrable virus which is the active cause of the disease, several contaminating organisms (8), such as *Pseudomonas aeruginosa* and various staphylococci. If the glycerol in the diluent inhibited the multiplication of these contaminators or disinfected them, it is reasonable to believe that the glycerol would affect the filtrable virus in a similar manner.

Technic

Virus of known virulence was used in making the standard and control vaccines; that is, it produced pronounced lesions of fowl pox within four to seven days after inoculation on scarified combs of susceptible birds. The standard vaccine contained 200 mgm. of virus suspended in 50 cc. of sterile 40 per cent glycerol-physiological saline solution. The control vaccine contained the same amount of virus suspended in sterile physiological saline solution alone. Immediately after manufacture and at times as stated in Table 4, both vaccines were cultured on agar slants and in poured Petri culture dishes of standard size. At first, second, and third dilution, plates were poured, but as these were sterile after incubation they were discontinued. When not in use the two vaccines were kept in an electric refrigerator at a temperature of from 45° to 50° F.

The agar used was made according to the usual formula of Bacto Peptone 10 grams, NaCl 5 grams, Liebig's beef extract 5 grams, Bacto Agar 20 grams per liter of distilled water. The hydrogen ion concentration was corrected to pH 7.2. Twelve centimeters of agar were used in the tubes for pouring plates.

At all times when the two vaccines were cultured, four plates were poured and four slants inoculated for each vaccine. One-tenth of 1 cc. of vaccine was added to each tube of cooled, melted sugar for plating and one loopful of vaccine thoroughly streaked over each agar slant. They were incubated for 24 hours, after which the number of colonies were counted. The Wolfhügel plate and mathematical computation were used when needed to count the plates. The respective averages of the four plates and four slants were computed and recorded as shown in the following table.

Table 4.—Action of Glycerol Content of the Diluent on the Contaminating Organisms in the Cutaneous Vaccine.

Age of vaccine when cultured, hours	CONTROL VACCINE SALINE DILUENT		STANDARD VACCINE GLYCEROL-SALINE DILUENT	
	Average number of colonies			
	4 plates	4 slants	4 plates	4 slants
Fresh	925.75	54.50	1582.00	66.25
24	667.75	17.66	938.00	44.25
48	315.00	10.25	274.75	12.75
72	128.75	21.50	108.25	8.00
90	175.50	18.00	114.50	5.00
142	327.00	19.25	50.25	3.00
166	264.50	20.50	25.25	1.50
190	261.75	17.50	20.25	1.25
214	340.50	18.50	25.00	.50
238	263.50	18.00	17.50	1.50
255	276.75	18.00	15.00	1.75
308	228.25	13.00	7.00	.50
332	236.00	16.25	9.25	.50
356	279.25	21.75	11.50	1.00
380	345.25	18.25	13.25	.50
423	154.00	11.00	6.75	Sterile
471	142.50	12.50	6.00	.50
495	119.00	13.75	11.50	.75
519	101.75	16.50	14.00	.50
538	611.50	53.75	14.25	.50
567	640.00	46.75	6.25	1.00
586	127.75	52.25	8.25	.25
615	1897.75	90.25	6.00	Sterile
635	709.00	127.75	4.00	Sterile
659	4840.00	162.50	4.50	Sterile
683	10414.25	311.25	11.25	Sterile
707	15431.00	670.00	10.00	.25

Interpretation.—A comparison of the control and standard vaccine plates in Table 4 shows that the glycerol content of the standard vaccine had a decided inhibiting and disinfecting action on the contaminating organisms in the vaccine. A comparison of slants shows a similar result. At the end of 707 hours the standard vaccine was nearly sterile as far as contaminating organisms were concerned. This near sterility was first noticeable at 423 hours. This is comparable with the attenuation of the vaccine, as described, which was marked when it was older than 25 days (600) hours.

A repetition of this experiment gave comparable results. The average number of colonies on four plates was 1.0 at the end of 567 hours, and the average number of colonies on four slants was 0 at the same time. The experiment was concluded at this point.

It seems reasonable to believe that, if the glycerol content of the standard vaccine had such an effect on the contaminators, it would also have a relatively similar effect on the filtrable virus. The results of the experiment indicate that this is so.

A 40 per cent content of glycerol has always been used in the standard cutaneous vaccine. Its disinfecting action, as shown above, precludes the use of phenol in the vaccine as a preservative. This content of glycerol serves to aid greatly in keeping the virus in suspension. There seems to be no reason for increasing the content of glycerol. It is probable that if the percentage were decreased the attenuation would not be so great. But after all, a low expiration date on a vaccine of this type is desirable, for it emphasizes the fact that the vaccine should be used when comparatively fresh. It has been repeatedly demonstrated that the unattenuated vaccine is the only efficient preventive against fowl pox.

Summary

Following a brief historical sketch of the subject, the cutaneous vaccine for fowl pox is described. Recommendations for its use and practical administration are given.

Two flocks containing 2,416 birds were vaccinated cutaneously just before being placed in the winter laying quarters. They remained free of fowl pox throughout the year. Annual outbreaks of the disease had occurred in these flocks for the four previous years. The gradual increase in early egg production was slightly retarded subsequent to the vaccination, beginning on the eighth or ninth day and ending on the twenty-first day after the treatment. The results of the work indicated that it was safe to vaccinate birds cutaneously as they were transferred from the range to laying houses, even though they were in early egg production at the time.

A slight increase in rectal temperature, averaging less than 1° F., occurred following cutaneous vaccination. The vaccination did not result in a retardation in the gain in weight of 80-day-old and 210-day-old birds. A slight retardation in gain in weight did occur, however, in 68-day-old birds. These results, however, were not considered as evidence against the vaccination of birds of such an age in such a manner.

The 100 milligram vaccine produced follicular swellings and scab formations comparable to the standard, the 300 milligram, and the commercial vaccines on birds of 68 and 80 days of age. Therefore, its use appeared to be indicated on birds of these ages.

The use of the standard cutaneous vaccine in a flock that was in the early stages of fowl pox infection and but slightly affected, apparently prevented further spread of the infection.

The results of inoculations with virulent virus suspensions on the combs of cutaneously immunized birds indicated that the duration of immunity was at least 371 days.

The glycerol content of the diluent had a decided inhibitory and disinfectant action on the contaminating organisms in the vaccine. Assuming that it had a relatively similar effect on the filtrable virus of the vaccine, the attenuation of the cutaneous vaccine as a result of aging may be thus explained.

Bibliography

(1) Van Heelsbergen, T.: Vaccination against diphtheria and fowl pox with Antidiphtherin. Vet. Rec., 1925, v, No. 24.

(2) Johnson, W. T.: Fowl pox prevention by immunization. Jour. Amer. Vet. Med. Assoc., 1927, lxxi, N. S. xxiv, 750-763.

(3) Pyle, Norman J.: Cutaneous immunity in relation to contagious epithelioma. Mass. Agr. Expt. Sta. Tech. Bul. 14, 1928.

(4) Edgington, B. H. and Broerman, Alvin: Fowl-pox and its prevention. Ohio Agr. Expt. Sta. Bimo. Bul. 135, 206-210, 1928.

(5) Sawyer, C. E.: Chicken pox. Western Wash. Expt. Sta. Ann. Rpt. N. S. 10-W, 43-46, 1928.

(6) Verge, Jean: Recherches Experimentales sur l'Affection Diphtero-Variolique des Oiseaux. 1926. 230 p. Toulouse, France: J. Bonnet.

(7) Besredka, A.: Local immunization. Edited and translated by Harry Plotz, 1927. 181 p. Baltimore, U. S. A.: Williams and Wilkins.

(8) Pyle, Norman J.: The therapeutic efficiency of avian diphtheria, roup. and bird pox vaccines and bacterins. Mass. Agr. Expt. Sta. Tech. Bul. 10, 1926.

(9) Beach, J. R.: The immunization of fowls against chicken-pox (Epithelioma contagiosum) by subcutaneous injection of virus. Hilgardia (Calif. Agr. Expt. Sta.), 1927, iii, 41-97.

Publication of this document approved by the
Commission on Administration and Finance

3m-1-'30. No. 7636

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 258 December, 1929

Inbreeding In Relation To Egg Production

By F A. Hays

For many years inbreeding has been successfully used in establishing poultry breeds where foundation stock was available only from very diverse sources. In recent years, however, work in this field has been confined largely to flocks of an established breed, and the value of inbreeding from such restricted foundation stock is questionable. The experiment here reported was planned to show the effect of various degrees of inbreeding within a so-called established breed — in this case Rhode Island Reds.

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INBREEDING IN RELATION TO EGG PRODUCTION

By F. A. Hays, Research Professor of Poultry Husbandry

Introduction

Inbreeding has been practiced for more than a century and a half by breeders of domestic animals as a method of establishing uniformity in herds and flocks. In the formation of new breeds the general policy has been to cross together several existing breeds or strains each carrying distinctive characteristics that were desired. The plan of matings for the polyhybrids thus obtained has generally been to select and inbreed the few animals showing desirable qualities until a degree of uniformity has been attained. Inbreeding was a necessity because few animals exhibited the characteristics desired and because it enabled breeders to "fix" the desired qualities. There is ample evidence in breed history to indicate that inbreeding has been advantageous in founding breeds where the original stock came from very diverse sources.

At present, evidence is not conclusive that inbreeding within a herd or flock of an established breed, and hence from a restricted foundation, is advantageous. This second type of inbreeding is comparable to most experimental inbreeding as carried on in recent years.

The very exhaustive analysis made by Wright (1922b, 1922c) of the results of inbreeding guinea pigs for 13 years using brother-sister matings led him to make two very significant deductions: 1. Compared with control stock derived from the same source as the inbreds and raised under identical conditions, the inbreds have undergone a genetic decline in vigor in all characteristics. The decline in fertility was most marked. The inbreds were less resistant to tuberculosis than the controls. Sex ratios were not affected by inbreeding. 2. Marked improvement immediately appeared in the progeny coming from crossing two inbred strains. This improvement was most pronounced through two generations of crossing inbred lines. Size of litter, body weight, disease resistance, livability and fertility were all greatly improved.

Extensive studies on the effects of inbreeding albino rats are reported by King (1918a, 1918b, 1918c). This worker found that after 15 generations of brother-sister matings, body weight averaged greater in inbreds than for controls. No decline in fertility or in vigor as measured by length of life was observed. High fecundity, early sexual maturity and vigorous growth all appeared to be inherited as a group in the inbreds. Sex ratio declined from 110 to 100 in 25 generations of inbreeding.

With reference to inbreeding poultry, published results are less exhaustive than those of Wright and King. Since the primary interest in this report is the effects of inbreeding upon characteristics concerned in fecundity in poultry, reference will be made to but a few reports on such phases of work.

Dunn (1923) reports the results of brother-sister matings in several lines using White Leghorns for a period of three years. He notes a decline in hatchability and in fecundity. Mortality rate both for chicks and laying pullets rose. Growth was slower and sexual maturity was delayed. His inbred flock was checked against similar unselected stock not inbred. The decline in reproductive power of his inbreds was so great as to preclude maintaining some lines. No selection is reported except on the basis of size of family. Dunn notes that the birds used in this experiment came from very restricted ancestry.

Hays (1924) reports some results from inbreeding Rhode Island Reds for three years. The report is concerned chiefly with characteristics known to affect fecundity. His results indicate that inbreeding did not affect body weight. Both fertility and hatchability showed decline. There was some evidence of reduced variability in winter egg production under inbreeding. Winter egg production showed a decline after the degree of inbreeding exceeds 25 per cent (Wright, 1922a, Coefficients of inbreeding).

Goodale (1927) presents data on White Leghorns using brother-sister matings through six generations. His data indicate some retardation in sexual maturity in successive generations. Body weight was not affected. Winter and annual egg yield also show a very perceptible fall. This investigator suggests the probability that more experience may enable the breeder to maintain brother-sister matings indefinitely.

Dunn (1927) reports further progress in inbreeding White Leghorns as well as the effects of crossing inbred lines. His results on inbreeding agree with those previously stated. No family has survived beyond the fifth generation of inbreeding. Of the four original families of 1920, only one remained in 1927, and of four families started since 1920 only two now survive. Hatchability declined in six years from 75 per cent to 41.5 per cent for the inbreds, while the controls increased from 49.8 per cent to 59.2 per cent. Dunn obtained very marked improvement in hatchability, mortality rate of chicks, body weight and sexual maturity by crossing inbred families. There was also increased winter egg production over that of inbreds, but these winter egg records were not equal to the records made by the foundation birds when the experiment began.

Experimental evidence, therefore, does not indicate that close inbreeding of fowls of a pure variety and from a restricted ancestral foundation is to be recommended in breeding for egg production.

Experiment at the Massachusetts Agricultural Experiment Station

The experiment reported here was begun in 1923 and closed in 1929. The fowls used were Rhode Island Reds bred for high fecundity since 1913. No outside stock was introduced between 1916 and 1923, but the foundation birds of the flock came from several rather diverse sources. Inbreeding was not practiced in developing the flock for high fecundity, but a considerable proportion of common blood had accumulated in the 10-year period so that the flock is rather closely bred.

Objects of the Experiment

The chief object of this experiment was to study the effects of different degrees of inbreeding upon characteristics affecting egg production in Rhode Island Reds and to further study the effects of heterosis on fecundity traits.

Plan of Experiment

A group of intensely inbred hens was mated to an outside male of "Standard" breeding to study effects of heterosis.

The check group included various degrees of heterosis (Group 1, 2 and 3) for the first three years, and for the last three years the checks were inbred.

Inbred groups began with four different degrees of inbreeding to found groups 4, 5, 6 and 7, and the inbred lines were crossed during the last three years of the experiment.

This experiment was planned to demonstrate: First, the effects of crossing a "Standard"-bred male upon intensely inbred hens from the production-bred flock; second, the effects of different degrees of inbreeding upon fecundity traits; third, the effects of inbreeding the outbred check group; fourth, the results from crossing the different inbred lines.

Inbred groups in this experiment represent a very narrow foundation in that one hen, C 1124, and three of her daughters furnish the female ancestry. The male ancestry of the inbred groups also falls into narrow limits in that the sire of the three foundation daughters was used, and the other two males were related to these females. Inbreeding birds from such a limited foundation should immediately uncover weaknesses as well as desirable qualities but should not be expected to have much effect on uniformity. On the other hand, where inbreeding is practiced with birds from diverse ancestry, greater uniformity in progeny should result. This last point may be studied in the check group of this experiment when the birds were inbred from 1926 to 1928.

Basis for Selection

Selection of breeders each year after 1923 whenever there were surplus birds to choose from was based on the following considerations: Genetic early maturity (Hays 1924), high intensity, no winter pause, non-broodiness and high persistency (Hays 1927). Selection was also made for high hatchability, low chick mortality, low mortality in the laying houses, heavy body weight and large families.

Attention should be called to the fact that the five heritable traits so intimately concerned in egg production are not measurable in males. Such circumstances add greatly to the difficulties of selecting breeding stock to improve such a complex characteristic as high fecundity. The progeny test of males appears the only possible method of handling this problem and such a method is far from exact.

Whenever a surplus of pullets and cockerels occurred, complete families were culled on the above basis. No culling was done in any family retained, and all pullets from families retained were kept to finish a full laying year if theiy survived. Only a superior sample (from a physical standpoint) of the cockerels from a family was kept after the family reached six months of age.

Table A records the number of matings, the number with resulting progeny, and the number eliminated, each year.

TABLE A — RECORD OF MATINGS AND PROGENY, 1923–1928

Mating Year	Matings Total Number		Matings with Progeny				Families Kept Number		Matings Eliminated *Per Cent*	
			Number		*Per Cent*					
	Checks	In-breds	Checks	In-breds	*Checks*	*In-breds*	Checks	In-breds	*Checks*	*In-breds*
1923 . .	4	4	4	2	*100*	*50*	4	1	*0*	*75*
1924 . .	8	7	5	7	*50*	*100*	5	7	*38*	*0*
1925 . .	7	9	2	6	*29*	*67*	2	4	*71*	*56*
1926 . .	3	13	3	11	*100*	*85*	2	7	*33*	*46*
1927 . .	9	28	9	25	*100*	*89*	5	9	*44*	*68*
1928 . .	8	24	7	14	*88*	*58*	3	8	*63*	*67*

Table A shows that during the first three years of the experiment when the check birds were outbred and the inbred lines carried as such, the number of matings was practically the same in each group. During the last three years there were 20 check matings and 65 inbred matings.

During the first three years 11 check matings and 15 inbred matings gave progeny. There was a rapid decline in percentage of successful matings in the check group. The inbred group, on the other hand, showed an increase in this respect in the second and third year over the first. These changes run almost parallel with hatchability records as will be noted under "Character of Female Breeders." When the check birds were inbred during the last three years of the experiment, practically all of the matings were successful. The former inbreds which were intercrossed during this period fell below the checks, yet they showed improvement over the initial three-year period when they were inbred.

The last two columns of the table indicate the number of families kept to be tested for egg production and from which to select future breeders, as well as the percentage of matings eliminated. Matings were eliminated by lack of progeny, very small numbers of progeny or for pronounced inferiority in desirable fedundity traits. This fact should be observed, however: that during the first three years of the experiment, all check families with offspring were retained and 12 out of 15 inbred families were kept. During the last three years of the experiment more culling was possible because more families were available. In 1926 two of the three check families with progeny were kept and 7 out of the 11 inbred families were kept. In 1927, 5 out of 9 check families were retained and only 9 out of 25 inbred families were kept. For 1928, 3 out of 7 check families were kept and 8 out of 14 inbred families were retained. These data, therefore, indicate that family culling for undesirable qualities was only possible during the last two years reported.

Elimination of families for all causes is shown in the last column of the table. The check group suffered less from elimination during the first three years when they were cross-bred and when no selection was practiced. The inbred group during the same period without selection lost 75 per cent of its possible families the first year, none the second year and 56 per cent the third year. In the last three-year period family losses in the checks were 33, 44, and 63 per cent, respectively, as compared with 46, 68 and 67 per cent for the inbreds. In general, these data indicate that losses of families were not greatly increased by inbreeding either in the original inbred groups or later in the check groups.

In the selection of breeders each year only the best available were utilized from the standpoint of fecundity traits. Theoretically such a procedure should make for progress, provided the standard for breeders was raised each year. The character of available material, however, often made raising the standard for breeders from year to year impossible as will be shown under "Character of Female Breeders."

Purpose of This Report

In the field of pedigree breeding there is a demand for specific information regarding the behavior of fecundity traits under inbreeding. These individual traits concerned in egg production have already been discussed in numerous publications from this Station. The outstanding purpose of this report is therefore to furnish specific information on the question of how inbreeding actually affects egg production by its influence upon known fecundity traits such as age at first egg, intensity, winter pause, etc. Since these fecundity traits are known to be inherited, it is necessary to consider each breeding female as a unit and each of her daughters as a unit to discover any possible effects of inbreeding on egg production. A general summary of results would be of little value in constructive breeding where attention must be focused upon individual traits or characteristics. This report therefore presents the necessary data on the characteristics being studied and will furnish a guide in pedigree breeding.

Method of Presenting Data

The data obtained in this experiment are presented in detail each year as the experiment progressed. The year's results are given under the following sections:

(1) Character of female breeders with respect to traits affecting egg production, together with annual egg records, hatching records and number of offspring; (2) mean egg weight, hatchability of dams, complete mean weight records for one year on surviving progeny, mortality in chicks to September 1, and mortality rate of pullets in the laying houses grouped by mothers; and (3) complete record of all surviving daughters with respect to traits affecting egg production, and annual egg record of each.

It is hoped that such a presentation will enable the reader to follow the results of each mating and to see at a glance why any particular mating gave the results indicated. It is also a simple procedure to discover improvements or faults introduced by crossing inbred lines as well as by inbreeding the check lines. Complete data are given rather than summaries because such records are necessary in studying a very complex characteristic like annual egg production. Moreover, genetic analyses only apply to the many individual traits affecting egg production when each trait is considered as a unit for each individual of a family; hence family averages or summaries are of small value as a working basis. An attempt is made in the comments following each table to show just why specific matings or types of matings are successful or otherwise.

Experimental Data on Effects of Heterosis

A supplementary test to the inbreeding experiment was made to study the effects of heterosis in 1923 and 1924. Six hens hatched in 1921 were used in this experiment. These birds were intensely inbred to B 357 for three generations. They were all mated as yearlings in the spring of 1923 to a "Standard"-bred cockerel from a prominent flock. The individual records of these hens are given below:

TABLE 1. — CHARACTER OF INBRED HENS

Bird No.	Age at First Egg	Weight at First Egg	Pause	Average Winter Clutch	Total Days Broody	Annual Persistency	Annual Production		1923 Hatchability	Offspring
							First Year	Second Year		
	Days	*Lbs.*	*Days*	*Eggs*	*Days*	*Days*	*Eggs*	*Eggs*	*%*	*No.*
C 1332	232	5.13	31	1.9	0	288	148	62	83	12
C 2084	221	5.06	4	2.1	0	262	173	165	80	25
C 3132	228	4.25	0	1.6	15	240	144	108	75	11
C 3544	205	5.13	0	3.1	0	208	119	Dead	53	6
C 3545	217	5.06	0	2.5	0	188	160	163	86	22
C 4014	168	4.38	0	5.4	32	252	162	87	52	6

The individual records of these inbred hens show that two of the six were genetically early maturing, that all were lacking in weight, that two-thirds were non-pause and one-third pause birds, only two were high in intensity, four were non-broody and two broody, all were lacking in persistency, all were poor layers, only one exhibited high hatchability, three medium hatchability and two low hatchability, and that the number of offspring from each was rather limited.

The cockerel (C 75450) to which the above hens were mated in 1923 came from a flock bred strictly for "Standard" qualifications. His weight was about 11 pounds when the breeding season began and he was true to "Standard" requirements, except for smut in the under-color. This male came from an outside source and was in no way related to the females with which he was mated.

If the unsatisfactory character of the above six hens from the egg production standpoint was due to low vigor resulting from inbreeding, mating with such a male would bring the stimulus of heterosis to the progeny and might enable the daughters to lay more eggs than their mothers. On the other hand, if the outside male used lacked the necessary inherited characteristics responsible for high production, the daughters would be low producers even though they carried the stimulus of heterosis.

Results of 1923 *Matings*

From the six hens mated to the above described cockerel, 82 progeny resulted. It is interesting to note the sex ratio of the chicks surviving to an age when the sex could be distinguished by external appearances. In the 72 chicks the sex of which was recorded, there were nearly twice as many males as females. These high sex ratios were not due to a pronounced higher post-natal mortality in female chicks because more than half of all chicks hatched were males. There may have been a higher death rate of females in the shell but this record was not obtained. The seasonal effects on sex ratio pointed out by Jull (1924), as well as the low antecedent production of the mothers, may in part explain the higher sex ratio observed.

TABLE 2. — HATCHING RECORDS OF MOTHERS WITH WEIGHT AND MORTALITY RECORDS OF THEIR SURVIVING PROGENY — 1923

Dam Number	Weight of Eggs Hatched	Hatch-ability	Offspring		Hatching Weight		Two-week Weight		Four-week Weight		150-day Weight		Weight at First Egg	Mortality		Weight at One Year	
			♂	♀	♂	♀	♂	♀	♂	♀	♂	♀		To Sept. 1	In Laying House	♂	♀
	Grams	%	*No.*		*Grams*		*Pounds*		*Pounds*		*Pounds*		*Pounds*	%	%	*Pounds*	
C 1332	52.2	83	9	1	33	34	.20	.22	.41	.41	4.97	4.42	6.40	17	0	–	6.38
C 2084	59.2	80	14	8	33	32	.22	.22	.52	.44	4.93	3.90	6.32	12	25	7.93	6.01
C 3132	51.2	75	8	2	32	34	.19	.19	.47	.37	5.14	3.56	5.60	9	0	8.32	5.65
C 3544	61.3	53	2	4	41	38	.26	.22	.59	.47	5.70	4.40	6.97	0	100	6.37	–
C 3545	55.3	86	10	9	34	35	.19	.20	.38	.45	4.70	4.20	6.15	18	50	7.81	5.92
C 4014	58.7	52	4	1	38	38	.28	.30	.64	.67	5.83	4.87	6.65	17	0	7.90	6.85
Average	**56.3**	**71**			**35**	**35**	**.22**	**.23**	**.50**	**.47**	**5.21**	**4.23**	**6.35**	**12.2**	**29.2**	**7.67**	**6.16**

♂ is the sign for male sex; ♀ is the sign for female sex.

Table 2 shows that the mean weight of eggs that actually hatched from the six different dams ranged from 51.2 grams to 61.3 grams, with a mean of 56.3 grams. The weight of eggs appeared independent of hatchability but was correlated with weight of chicks. Large eggs did not give more vigorous chicks than small eggs as judged by mortality rate up to September first.

These data do not indicate that the percentage of fertile eggs hatched, termed hatchability, is any indication of the probable mortality rate in chicks up to September first, and these data agree with those of Dunn (1922).

Male and female chicks did not differ in weight when taken from the incubator. At four weeks of age males began to weigh more than females. The weight difference for the sexes became very pronounced at 150 days when the cockerels weighed practically one pound more than the pullets, or about 23 per cent. At one year of age, males averaged 7.67 pounds and females 6.16 pounds. Mortality rates for pullets in the laying houses were excessive so that the number of complete annual egg records is very small.

In studying the effects of heterosis upon the characteristics known to affect egg production, it seems advisable to consider only those daughters which lived to finish their first laying year. The data are presented in Table 3.

TABLE 3. — RECORD OF ALL SURVIVING DAUGHTERS FROM THE 1923 MATINGS

Dam No.	Bird No.	Age at First Egg	Weight at First Egg	Pause	Average Winter Clutch	Total Days Broody	Annual Persistency	Annual Production
		Days	*Lbs.*	*Days*	*Eggs*	*Days*	*Days*	*Eggs*
C 1332 .	C 9126	213	6.40	48	1.4	0	250	119
C 2084 .	C 7311	338	7.10	–	–	45	180	101
	C 8395	228	6.24	0	1.2	0	151	114
	C 8690	228	6.79	13	1.8	22	251	155
	C 9176	238	5.90	29	1.3	24	257	136
C 3132 .	C 7696	204	5.60	44	1.3	0	230	88
C 3545 .	C 7876	272	6.49	8	1.5	0	249	86
	C 9138	237	6.37	0	2.4	0	143	165

By comparing Table 3 with Table 1, it is possible to discover differences between mothers and daughters which may be assigned largely to the sire used. By this method, something of the effects of heterosis on traits concerned in egg production may be disclosed.

Age at sexual maturity was affected. Two mothers known to be genetically early maturing unfortunately failed to produce any of the daughters with complete records. Thus all the daughters in Table 3 came from late-maturing mothers. But the actual age at which these daughters began laying generally exceeded that of their dams. The fact seems evident, therefore, that this mating did not reduce the age at sexual maturity in the daughters of these inbred mothers.

The body weight of these pullets when they laid their first egg showed the pronounced effect of heterosis. Every individual daughter weighed more than her dam at first egg, and the mean weight of all daughters at first egg was about 32 per cent greater than that of the dams.

The effect of heterosis on winter pause was apparently insignificant. Inasmuch as six of the daughters came from pause dams and only two from a non-pause dam, it is probable that heterosis had no effect on winter pause.

Intensity as measured by winter clutch size ran low in the daughters. Since the two dams C 3544 and C 4014 that evidently carried genes for high intensity had no daughters with complete records, there could be no intense daughters unless male C 75450 transmitted high intensity. This male evidently lacked the genes for high intensity for his daughters laid in smaller clutches than their dams.

Effects of heterosis on broodiness were not apparent in the daughters studied. Male C 75450 apparently did not increase the degree of broodiness as his daughters show no greater proportion of broody individuals than existed in the inbred mothers to which he was mated.

No genetically persistent daughters appeared in Table 3. Since the inbred mothers used were lacking in persistency, it is evident that the sire of these daughters also lacked the gene P for high persistency.

In pullet-year egg production these hybrid daughters were inferior to their dams. This may be explained by their late maturity, low intensity and lack of persistency.

The only recognizable benefit that came from heterosis in these matings was marked increase in body weight. From the standpoint of annual egg production, no benefits were derived. Male C 75450 was evidently lacking in early maturity, high intensity and high persistency.

1924 *Matings*

In order to test further the effects of heterosis, it seemed advisable to continue the matings in 1924. Successful matings were obtained from but two of the hens used in 1923 (Nos. C 1332 and C 3132). These two inbred hens were mated to a cockerel (C 7954) sired by C 75411, an outside "Standard"-bred male from the same source as male C 75450 used in 1923. Cockerel C 7954 was a son of C 6286, a Station hen that was not inbred.

The observation was made that the progeny of 1923 were slightly heavier than those of 1924 from hens C 1332 and C 3132. It was noted also that there was no mortality of daughters from these two hens in the laying houses for the year 1923; while the mortality rate was 33 and 50 per cent, respectively, for 1924. Evidently the direct outcross made in 1923 gave more vigorous offspring than the less pronounced outcross of 1924.

Early sexual maturity was apparently not affected by inbreeding and came as a dominant from the dams both years. Winter pause occurred in all 1924 daughters and was expected from the two dams used. Both dams used in 1924 lacked high intensity, but one daughter was high in intensity, showing that the sire must have contributed genes for high intensity. The first dam was non-broody but had one daughter showing broodiness. The second dam carried broodiness and her one daughter was not broody. These facts suggest that the first hen carried one gene for broodiness and that the male used carried the other broody gene. Both the dams for 1924 were low in persistency. The fact that 4 out of the 5 daughters were persistent shows that male C 7954 carried P, the gene for high persistency. The annual egg records of the five birds hatched in 1924 were higher than for the birds hatched in 1923, indicating the importance of high intensity and high persistency.

In general, the results of outcrossing on two successive years indicated that body weight may be increased and vigor somewhat improved in the first generation, but that undesirable traits from the standpoint of fecundity will be introduced unless the outcross is made with stock carrying the characteristics necessary to heavy egg production. This type of mating was not continued after 1924 and the progeny of 1924 were not used for breeding.

Inbreeding Experiment

In the spring of 1923 an experiment was begun using Rhode Island Reds to test the effects of different degrees of inbreeding upon the characteristics directly affecting fecundity and upon other characteristics of importance in breeding for high egg production. The plan was to establish several inbred groups representing different degrees of inbreeding and to continue these groups as such for a period of years. It was also thought necessary to establish several definite types of check groups with which to compare the different inbred groups.

Plan of Matings — 1923

Birds Available.—In the 1923 matings one hen (No. C 1124) and six of her daughters were used, one inbred hen (C 4746) coming from brother-sister mating, one outside "Standard"-bred male (C 75411), one male (C 5085) from brother-sister mating, male C 4658 not inbred but of straight Station breeding, male C 4884 a half brother (common sire) to the six sisters used in the experiment, and male C 1616 the sire of the six sisters used. Male C 1616 was out of hen B 8316 with a pullet year record of 279 eggs. She was broody three times. His paternal granddam was B 699 with a record of 222 eggs and non-broody. His maternal granddam had a record of 186 and was non-broody. Male C 1616 had a very mediocre progeny record in 1922 in that his daughters from three hens averaged only 166 eggs. All birds were single comb Rhode Island Reds and all had been bred without introducing outside stock for seven years until males C 75411 and C 75450 were brought in as cockerels for these experiments from a "Standard"-bred flock.

Check Groups.

1. Two full sisters (not inbred) Nos. C 6127 and C 6286, mated to "Standard"-bred male C 75411.
2. A third sister (C 5465), mated to inbred male C 5085 coming from brother-sister mating.
3. An inbred female (C 4746) from brother-sister mating, mated to "Standard"-bred male C 75411.

Inbred Groups.

4. A fourth sister (C 6287), mated to her cousin (C 4658).
5. A fifth sister (C 5746), mated to her half brother (C 4884) (common sire).
6. Foundation dam (C 1124), mated to her nephew (C 4658).
7. A sixth sister (C 5745), mated to her sire (C 1616).

TABLE 4. — CHARACTER OF FEMALE BREEDERS — 1923

Group No.	Bird No.	Age at First Egg	Weight at First Egg	Pause	Average Winter Clutch	Total Days Broody	Annual Persistency	Annual Production	1923 Hatchability	Offspring
		Days	*Lbs.*	*Days*	*Eggs*	*Days*	Days	*Eggs*	%	*No.*
1	C 6127	161	5.31	40	1.9	0	356	166	76	13
1	C 6286	168	5.31	20	3.3	0	350	226	88	22
2	C 5465	176	5.38	9	2.4	0	365	171	36	6
3	C 4746	192	5.81	54	3.7	0	365	214	89	18
4	C 6287	184	5.88	0	3.6	Died in April, 1923			–	–
5	C 5746	186	5.06	8	1.9	Died in March, 1923			36	3
6	C 1124	176	4.81	22	4.3	13	365	238	79	13
7	C 5745	172	5.00	17	3.0	16	*Injured*		–	0

Table 4 shows the character of the females used as breeders for their pullet-laying year. Attention is again directed to the fact that all of the above females, except C 4746 and C 1124, were full sisters, and that C 1124 was their mother and C 4746 was a closely inbred hen. A marked degree of uniformity in age at first egg was exhibited by these six sisters, the range being between 161 and 186 days. All were genetically early maturing.

These six sisters were also rather uniform in body weight at first egg, ranging from 5.00 to 5.88 pounds. Foundation dam C 1124 was a small hen weighing but 4.81 pounds when she laid her first egg.

Winter pause was shown by all the sisters, except C 6287, and was present in the foundation hen C 1124 and inbred hen C 4746. Lines of birds descending from such a foundation would, therefore, be expected to carry winter pause.

The characteristic intensity or clutch size in the six sisters was variable. Three of the birds probably carried both genetic factors for large clutch size, and the other three were low for intensity. Both foundation hen C 1124 and inbred hen C 4746 were high in intensity.

Broodiness was present in but one of the four sisters completing the year. Inbred hen C 4746 was non-broody, but foundation hen C 1124 carried broodiness in the pullet year.

All of the females with a complete record showed high persistency. Such foundation females should therefore be very satisfactory foundation breeders from the standpoint of high persistency.

Only three of the sisters had a complete annual egg record. These records were 166, 171 and 226. Hen C 6286 was able to make a record of 226 eggs because she carried early maturity, high intensity and high persistency. The other two sisters were notably deficient in intensity. Inbred hen C 4746 carried early maturity, high intensity, high persistency and non-broodiness but showed a long winter pause. Her record was 214 eggs. Foundation hen C 1124 laid 238 eggs. She carried winter pause and broodiness as major defects. On the whole, such foundation females could not be expected to establish superior lines for egg production under inbreeding because they possessed too many undesirable characteristics.

Results of Matings — 1923

The sex ratio observed in chicks living until their sex could be recorded by external appearances is of little value the first year of the experiment because of the small number of offspring. In the check groups there were 18 males and 31 females, and 6 males and 6 females came from the one successful inbred mating.

TABLE 5. — HATCHING RECORDS OF MOTHERS, WITH WEIGHT AND MORTALITY RECORDS OF THEIR SURVIVING PROGENY — 1923

Group Number	Dam Number	Weight of Eggs Hatched	Hatchability	Off-spring		Hatching Weight		Two-week Weight		Four-week Weight		150-day Weight		Weight at First Egg	Mortality		Weight at One Year	
				♂	♀	♂	♀	♂	♀	♂	♀	♂	♀		To Sept. 1	In Laying House	♂	♀
		Grams	%	*No.*		*Grams*		*Pounds*		*Pounds*		*Pounds*		*Pounds*	%	%	*Pounds*	
Check Group 1	C 6127	58.0	76	6	5	37	36	.24	.20	.57	.40	5.33	3.84	6.33	15	0	9.81	5.46
	C 6286	55.8	88	5	15	35	35	.22	.23	.47	.50	4.56	3.97	6.29	18	23	8.46	6.02
Check Group 2	C 5465	56.0	36	1	2	34	34	.19	.19	.42	.41	4.23	3.30	5.70	50	100	7.62	–
Check Group 3	C 4746	60.0	89	6	9	41	40	.31	.27	.69	.53	6.34	4.43	6.79	17	67	9.90	5.75
Average — check groups		**57.5**	**72**			**37**	**36**	**.24**	**.22**	**.54**	**.46**	**5.12**	**3.89**	**6.28**	**25.0**	**47.5**	**8.95**	**5.74**
Inbred Group 6	C 1124	55.5	79	6	6	36	36	.25	.22	.56	.46	5.20	4.10	5.69	8	50	8.04	5.71

Table 5 shows that all but two of the dams laid eggs under the standard weight of 56.7 grams. There was no indication, however, of any relationship between weight of eggs and hatchability. One of the sisters (C 5465) showed very low hatchability.

Chick weight at hatching was correlated with egg weight in this table. Mortality rate in chicks up to September first tended to run higher from the low hatching mothers.

The inbred female progeny of C 1124 sired by her nephew were slightly lighter in weight at first egg than were the daughters of any of the other hens. This may be due entirely to the fact that C 1124 was a smaller hen than any of the others and not be a concomitant of inbreeding.

The mortality rate in the laying houses was conspicuously greater in the inbred progeny from C 1124 than from check group 1, but check group 3 shows a higher rate than the daughters of C 1124. The number of offspring from check group 2 was inadequate to be of statistical value.

TABLE 6. — RECORD OF ALL SURVIVING DAUGHTERS FROM THE 1923 MATINGS

Dam No.	Bird No.	Age at First Egg	Weight at First Egg	Pause	Average Winter Clutch	Total Days Broody	Annual Persistency	Annual Production
		Days	*Lbs.*	*Days*	*Eggs*	*Days*	*Days*	*Eggs*
			Check Group 1					
C 6127 . .	C 9023	298	6.14	–	–	25	128	82
C 6286 . .	C 7538	311	–	10	1.0	0	252	158
	C 7539	227	6.63	8	2.1	22	217	95
	C 7955	223	6.81	16	2.4	17	366	201
	C 7956	225	5.82	21	3.4	38	138	151
	C 7957	197	6.35	35	3.3	0	366	175
	C 8533	216	5.00	0	1.8	0	307	193
	C 8851	226	6.00	56	1.4	0	250	94
	C 9039	218	5.35	17	1.6	0	244	155
			Check Group 3					
C 4746 . .	C 7718	235	7.24	9	3.1	19	351	167
	C 8746	237	7.20	0	1.7	20	221	137
			Inbred Group 6					
C 1124 . .	C 8364	222	6.00	0	2.5	0	349	215
	C 8365	203	6.05	7	2.1	0	359	222
	C 8645	192	5.37	27	2.5	0	339	219

Check Group 2 — Two daughters which died before the end of the year.
Inbred Group 4 — All eggs were infertile.
Inbred Group 5 — Three chicks, all died in April.
Inbred Group 7 — Only one chick produced.

Inbred daughters may be compared with the check daughters in Table 6. The inbred daughters were smaller when they laid their first egg, were superior in early maturity and in absence of winter pause, carried somewhat higher intensity, were free from broodiness, and were more persistent layers. The annual egg records of the checks averaged about 150 eggs while the inbreds averaged 219 eggs. These data agree with those already presented in that by securing heterosis many desirable fecundity traits may be sacrificed unless much care is taken in selecting the outside stock for desirable fecundity traits.

Plan of Matings — 1924

Much difficulty was experienced because of losses, in making the matings for 1924 conform with the plan of 1923.

Check group 1 was made up of four pullets hatched in 1923. These were two daughters from each of the original full sisters used in 1923. These four pullets were mated in 1924 to an unrelated cockerel from a very heavy laying family of straight Station breeding. Check group 1 was therefore made up in 1924 of hybrid pullets mated to a male of pure Station breeding.

Check group 2 again consisted of hen C 5465 with the addition of one of her daughters, C 8808. These two birds were mated to male C 5055 that was inbred coming from half brother-sister mating, but he was also half brother to C5465 and related to her daughter.

Check group 3 again included inbred hen C 4746 and the group was supplemented by two of her daughters, C 7718 and C 7719. Hen C 4746 was again mated to the outside male C 75411 and her two daughters from this mating in 1923 were mated to the unrelated production-bred male C 7494 that was used in group 1.

Inbred group 4 consisted of one of the original sisters C 6127 mated to male C 4658. The mothers of these two birds were full sisters and their sires were half brothers, thus making an approach to brother-sister mating.

Inbred group 5 was made up of one of the original sisters C 6286 mated to her half brother, both having a common sire. To this group were added two inbred sisters (brother-sister mating). These last two birds were mated to male C 8289 whose dam was B 8254 the identical paternal and maternal granddam of his mates.

Inbred group 6 contained foundation hen C 1124 mated to her son C 8086, and this son was sired by a son of her full sister.

Inbred group 7 consisted of two sisters C8079 and C 8333 linebred to B 699 and mated to male C 8354 also linebred to B 699.

TABLE 7 — CHARACTER OF FEMALE BREEDERS — 1924

Group No.	Bird No.	Age at First Egg	Weight at First Egg	Pause	Average Winter Clutch	Total Days Broody	Annual Persistency	Annual Production	1924 Hatchability	Offspring
		Days	*Lbs.*	*Days*	*Eggs*	*Days*	*Days*	*Eggs*	*%*	*No.*
1	C 7970	228	7.02	0	3.3	0	Sick in June		0	0
1	C 8545	231	6.75	–	–	–	Sick in June		–	0
1	C 7539	227	6.63	8	2.1	22	217	95	0	0
1	C 7957	197	6.35	35	5.3	0	366	175	13	1
2	C 5465	176	5.38	9	2.4	0	365	171	43	15
2	C 8808	183	5.70	28	3.3	Died in July			68	21
3	C 4746	192	5.81	54	3.7	0	365	214	44	12
3	C 7718	235	7.24	9	3.1	19	355	167	11	3
3	C 7719	291	7.45	14	1.1	Died in September			0	0
4	C 6172	161	5.31	40	1.9	0	356	166	93	21
5	C 6286	168	5.31	20	3.3	0	350	226	64	7
5	C 4577	184	5.63	0	2.4	0	365	216	13	2
5	C 6192	198	5.19	0	2.5	0	353	248	43	6
6	C 1124	176	4.81	22	4.3	13	365	238	78	7
7	C 8079	209	6.10	7	1.3	0	350	188	72	21
7	C 8333	205	5.35	0	3.0	Died in May			68	21

Table 7 discloses that 5 out of the 9 females used as check breeders were late maturing and that none of the birds used in the inbred groups was late maturing. These late maturing birds were all sired by the "Standard" color male C 75411 introduced from an outside source, and they serve to illustrate the results of mating early maturing hens to a late maturing male.

In weight at first egg the check groups excelled the inbred groups and showed the effects of heterosis. All of the inbred birds exhibited satisfactory weight at first egg, however, with the single exception of hen C 1124.

Winter pause was prevalent in the female breeders used in 1924 as in 1923. One check female, two in inbred group 5 and one in inbred group 7 did not exhibit winter pause.

Intensity measured by mean winter clutch was not greatly different from the records for 1923. Five of the nine check birds were genetically intense and four lacked intensity. Three of the seven inbred mothers carried high intensity in 1924, as compared with three out of four in 1923. Apparently intensity was not holding up in the first generation of inbred daughters.

In the check groups two broody and four non-broody birds were used in 1924, compared with all non-broody females in 1923. Only one out of six of the inbred mothers of 1924 was broody compared with all broody in 1923. There was therefore an apparent gain in non-broodiness over 1923.

Only one female breeder of 1924 lacked genetic high persistency and she was check bird C 7539. All of the breeders of 1923 were highly presistent and the trait seemed to carry on in 1924.

Annual egg records for all check mothers made during their pullet year were very mediocre with the single exception of C 4746 in group 3. The inbred mothers of 1924 were for the most part very good layers, but C 6127 in group 4 and C 8079 in group 7 were both mediocre layers.

Reference to the 1924 hatching records of these birds indicates that the inbreds were decidedly superior to the checks. The best hatching record was made by C 6127 mated to a rather closely related male. The inferior hatching records of most of the checks must be due to the outside bloodline introduced. The numbers of offspring obtained from many of the matings were inadequate for analytical purposes.

Results of Matings — 1924

The sex ratio of surviving chicks from the check group was 115 to 100, while the ratio in the inbred chicks was 82 to 100. This fact would suggest that inbred males were less able to survive in the early struggle for existence than were the check males. The detailed data do not indicate, however, that inbreeding as such actually reduced the sex ratio.

TABLE 8. — HATCHING RECORDS OF MOTHERS, WITH WEIGHT AND MORTALITY RECORDS OF THEIR SURVIVING PROGENY — 1924

Group Number	Dam Number	Weight of Eggs Hatched	Hatchability	Offspring		Hatching Weight		Two-week Weight		Four-week Weight		150-day Weight		Weight at First Egg	Mortality		Weight at One year	
				♂	♀	♂	♀	♂	♀	♂	♀	♂	♀		To Sept. 1	In laying House	♂	♀
		Grams	%	*No.*		*Grams*		*Pounds*		*Pounds*		*Pounds*		*Pounds*	%	%	*Pounds*	
Check Group 1	C 7957	56.0	13	0	1	–	37	–	.24	–	.61	–	4.89	6.45	0	0	–	5.45
Check Group 2	C 5465	62.7	43	7	5	41	37	.24	.22	.61	.50	5.47	4.27	5.45	20	100	7.80	4.23
	C 8808	57.8	68	8	8	36	34	.22	.22	.59	.54	5.80	4.48	6.48	29	63	7.50	5.04
Check Group 3	C 4746	68.3	41	8	4	44	45	.24	.23	.63	.57	6.20	4.88	7.15	0	33	8.45	6.46
	C 7718	59.7	11	0	2	–	38	–	.26	–	.60	–	4.16	6.49	33	50	–	5.16
Average — check groups		**60.9**	**36**			**40**	**38**	**.23**	**.23**	**.61**	**.56**	**5.82**	**4.54**	**6.40**	**16.4**	**49.2**	**7.92**	**5.72**
Inbred Group 4	C 6127	63.6	93	8	12	40	39	.23	.21	.54	.52	5.74	4.28	5.90	10	56	8.40	5.00
Inbred Group 5	C 6286	63.1	64	2	5	40	39	.22	.24	.57	.59	5.85	3.93	5.15	0	100	5.70	4.62
	C 4577	62.5	13	0	1	–	40	–	.20	–	.52	–	3.83	5.40	50	100	–	–
	C 6192	52.8	43	1	5	32	32	.10	.18	.30	.46	–	4.09	5.02	0	40	–	4.58
Inbred Group 6	C 1124	55.0	78	4	3	33	35	.18	.14	.47	.35	5.02	3.73	5.92	0	100	–	4.82
Inbred Group 7	C 8079	63.3	72	12	3	37	35	.21	.19	.51	.46	5.39	4.40	5.95	33	33	8.07	5.32
	C 8333	52.7	68	4	9	31	30	.19	.16	.47	.40	6.09	4.00	5.11	38	67	–	4.10
Average — inbred groups		**59.0**	**62**			**36**	**36**	**.19**	**.19**	**.48**	**.47**	**5.62**	**4.04**	**5.49**	**18.7**	**70.9**	**7.39**	**4.74**

A comparison of Table 8 with Table 5 at once emphasizes the superior character of the 1924 dams in egg size. In 1923 only two dams laid a standard weight egg of 56.7 grams, while in 1924 four of the five check dams laid standard weight eggs and four of the seven inbred dams laid eggs of standard weight.

Hatchability ran higher in the inbred groups than in the checks. In fact, only one check hen reached medium hatchability. Egg weight and chick weight were again closely correlated. Chick mortality rates to September first were very slightly higher in the inbred groups than in the checks. These data do not indicate an important relationship between the percentage of fertile eggs hatched and the percentage of range mortality.

The mean number of offspring per mother did not differ greatly in the check group and the inbred group for the mothers actually producing chicks, but there were more unsuccessful matings among the checks than among the inbreds.

A comparison of the weight records of offspring for one year shows that the check birds were decidedly heavier than the inbreds from hatching time on. A significant difference in the weight of males and females did not appear until four weeks of age. Table 8 also shows that the mean weight of pullets was greater at first egg than at the age of one year. This difference was not due to a loss of weight during the year but to the fact that the mortality rate in the laying houses was greater among the heavy birds both in the check and in the inbred groups.

Mortality rates for pullets in the laying houses were decidedly high. Several of the families were completely obliterated. The gross mortality rate for the inbreds was significantly greater than for the checks. These losses were augmented by a severe epidemic of pox and roup attacking all the flock.

TABLE 9. — RECORD OF ALL SURVIVING DAUGHTERS FROM THE 1924 MATINGS

Dam No.	Bird No.	Age at First Egg	Weight at First Egg	Pause	Average Winter Clutch	Total Days Broody	Annual Persistency	Annual Production
		Days	*Lbs.*	*Days*	*Eggs*	*Days*	*Days*	*Eggs*
				Check Group 1				
C 7957 . .	E 208	186	6.45	56	1.7	0	365	168
				Check Group 3				
C 7718 . .	E 220	321	6.90	0	1.4	0	306	239
				Inbred Group 4				
C 6127 . .	E 654	315	5.85	0	1.8	0	131	170
	E 2132	192	5.12	0	2.4	30	171	134
				Inbred Group 5				
C 6192 . .	E 425	177	5.15	4	4.1	0	365	225
	E 611	179	5.44	21	2.0	0	365	203
	E 666	181	4.97	15	2.8	29	172	213
				Inbred Group 7				
C 8079 . .	E 876	233	6.17	5	1.5	0	316	170
	E 2343	226	6.12	0	2.5	16	151	102
C 8333 . .	E 914	185	5.57	19	2.7	38	365	183
	E 2352	204	5.10	0	2.2	0	130	158
	E 2353	184	4.88	13	2.2	0	217	138

Check Group 2 and Inbred Group 6 had no complete records.

Table 9 shows that the three check groups of 1924 were practical failures from the standpoint of reproduction. Only two daughters from the three check groups survived to complete the laying year. The character of the parents used in 1924 would make for less heterosis than existed in 1923, and this may in part explain the high mortality of 1924, yet cross-breeding as such did not appear to increase vigor as measured by laying house mortality. The fragmentary records would indicate that broodiness was reduced in the check birds but that intensity was lower than in 1923.

Judging the results of inbreeding by the progeny record leads to the deduction that only group 5 was successful and gave satisfactory egg production. In this group the three daughters recorded are all from hen C 6192 whose sire and dam were full brother and sister. She was mated in 1924 to a son of her single granddam. The three daughters in group 5 were all inferior to their dam in fecundity, however.

In group 7 the daughters were all mediocre producers. The first two were from C 8079 and the last three from C 8333. Both of these dams were early maturing but the first gave only late daughters. These daughters represented line breeding to hen B 699 with a record of 222 eggs. They exhibited no improvement over their dams and showed no advantages in line-breeding.

In general, the inbred birds were satisfactory in weight but the tendency to late sexual maturity appeared. Many of them lacked persistency and nearly all lacked vigor. They did not exhibit marked uniformity in characteristics affecting fecundity.

Plan of Matings — 1925

Check group 1 again consisted of four outbred daughters hatched in this group in 1923. These were mated in 1925 to an intensely production-bred male unrelated to them but a full brother to the male used in this group in 1924.

Check group 2 still included the original sister C 5465 but she was mated to a male, E 1824, that was inbred to her sire.

Check group 3 was made up of inbred hen C 4746 again mated to outside male C 75411. A male, C 7984, from the heavy producing strain was also mated to a hybrid pullet, C 7718, coming from mating male C 75411 to an inbred hen.

Inbred group 4 again included hen C 6127 mated to C 8086. Both of these birds were out of foundation hen C 1124 but were not related on the sire's side. They were half brother and sister.

Inbred group 5 contained the original sister used in 1924 mated to her son who was inbred to foundation male C 1616.

Inbred group 6 was made up of two inbred daughters of foundation hen C 1124 mated to her son that was also related to his mates on the paternal side. Hen C 1124 was also mated to her son C 8086, the same male as in 1924.

Inbred group 7 contained hen C 8079 mated to her son E 1592, and three of her daughters mated to their brother.

Table 10. — Character of Female Breeders — 1925

Group No.	Bird No.	Age at First Egg	Weight at First Egg	Pause	Average Winter Clutch	Total Days Broody	Annual Persistency	Annual Production	1925 Hatchability	Offspring
		Days	*Lbs.*	*Days*	*Eggs*	*Days*	*Days*	*Eggs*	*%*	*No.*
1	C 7538	311	–	10	1.0	0	252	158	75	3
1	C 7539	227	6.63	8	2.1	22	217	95	Died in March	
1	C 8851	226	6.00	56	1.4	0	250	94	All infertile	
1	C 9023	298	6.14	–	–	25	128	82	Died in April	
2	C 5465	176	5.38	9	2.4	0	365	171	No eggs	
3	C 4746	192	5.81	54	3.7	0	365	214	All infertile	
3	C 7718	235	7.24	9	3.1	19	351	167	67	4
4	C 6127	161	5.31	40	1.9	0	356	166	75	9
5	C 6286	168	5.31	20	3.3	0	350	226	100	4
6	E 540	355	–	–	–	–	–	–	All infertile	
6	E 795	249	5.92	0	1.6	–	–	–	All infertile	
6	C 1124	176	4.81	22	4.3	13	365	238	67	2
7	C 8079	209	6.10	7	1.3	0	350	188	78	14
7	E 876	233	6.17	5	1.5	0	316	170	56	5
7	E 1934	197	5.56	4	1.7	–	–	–	All infertile	
7	E 2343	226	6.12	0	2.5	16	151	102	29	2

Table 10 presents the characteristics of the female breeders used in 1925. The general inferiority of these birds compared with the foundation females used in 1923, shown in Table 4, is very evident. The check birds tended to late maturity and to heavy body weight. They also tended toward low intensity and to very mediocre egg production. The hatching records for the checks were decidedly inferior, and only seven chicks were produced.

The inbred birds showed less tendency to late maturity than did the checks. The inbreds were also of satisfactory weight, but many of them were low in intensity. They were satisfactory from the standpoint of non-broodiness and persistency, but their annual egg records were lower than for the foundation mothers of 1923. Hatching records were poor so that only 36 chicks were produced.

Results of Matings — 1925

The number of progeny produced from the 1925 matings was too small for studying the sex ratios. Their complete weight and mortality records are given in Table 11.

TABLE 11. — HATCHING RECORDS OF MOTHERS, WITH WEIGHT AND MORTALITY RECORDS OF THEIR SURVIVING PROGENY — 1925

Group Number	Dam Number	Weight of Eggs Hatched	Hatchability	Offspring		Hatching Weight		Two-week Weight		Four-week Weight		150-day Weight		Weight at First Egg	Mortality		Weight at One Year	
				♂	♀	♂	♀	♂	♀	♂	♀	♂	♀		To Sept. 1	In Laying House	♂	♀
		Grams	%	*No.*		*Grams*		*Pounds*		*Pounds*		*Pounds*		*Pounds*	%	%	*Pounds*	
Check Group 1	C 7538	64.3	75	0	2	–	42	–	.19	–	.45	–	4.75	6.45	33	0	–	7.53
Check Group 3	C 7718	65.0	67	2	2	44	41	.23	.23	.56	.49	–	4.62	5.49	0	0	–	5.65
Average — check groups		**64.7**	**71**			**44**	**42**	**.23**	**.21**	**.56**	**.47**	–	**4.69**	**5.97**	**16.5**	**0**	–	**6.59**
Inbred Group 4	C 6127	62.9	75	3	4	40	40	.21	.17	.52	.36	5.31	4.42	5.78	22	50	8.55	6.58
Inbred Group 5	C 6286	61.0	100	2	1	38	39	.15	.20	.35	.48	3.77	3.53	4.55	50	0	–	4.55
Inbred Group 6	C 1124	53.0	67	1	0	31	–	.12	–	.27	–	4.32	–	–	50	–	–	–
Inbred Group 7	C 8079	62.8	78	5	3	37	40	.16	.17	.30	.42	3.63	4.31	5.81	50	33	7.73	5.97
	E 876	53.8	56	0	1	–	32	–	.15	–	.30	–	3.78	5.25	80	0	–	5.27
Average — inbred groups		**58.7**	**75**			**37**	**38**	**.16**	**.17**	**.36**	**.39**	**4.26**	**4.01**	**5.35**	**50.4**	**20.8**	**8.14**	**5.59**

Table 11 gives some information concerning the breeding ability of the females used in 1925. Egg weight was appreciably above the standard of 56.7 grams, or 24 ounces per dozen, except for foundation hen C 1124 and hen E 876, that came from a high fecundity strain.

Hatchability was far superior to 1924 and none of the birds fell below medium hatchability. Eggs weighing about 61 grams showed higher hatchability than either larger or smaller eggs. The correlation between egg weight and chick weight at hatching stands out prominently.

Hatching weights of chicks did not indicate that the sexes differed significantly, or that weight could be used as a basis for distinguishing sex of day-old chicks.

Mortality in chicks up to September first ran significantly higher in the inbred groups than in the checks. Those groups closely inbred showed a mortality of 50 per cent or more. These data would appear as something of an indication of low vigor in the inbreds.

The data on weight records given in Table 11 are too meager to be of great value. They do, however, point to a few general tendencies. In the first place, the check birds tended to be heavier at a given age than the inbreds. There was no mortality in the laying houses for the check pullets, while the mortality for some of the inbred families reached 50 per cent. There is general evidence that the inbreds were less vigorous than the checks.

TABLE 12.— RECORD OF ALL SURVIVING DAUGHTERS FROM THE 1925 MATINGS

Dam No.	Bird No.	Age at First Egg	Weight at First Egg	Pause	Average Winter Clutch	Total Days Broody	Annual Persistency	Annual Production
		Days	*Lbs.*	*Days*	*Eggs*	*Days*	*Days*	*Eggs*
Check Group 1								
C 7538 . .	F 7	206	6.45	65	1.3	0	346	124
Check Group 3								
C 7718 . .	F 525	193	5.78	41	2.6	0	352	205
	F 943	167	5.20	65	2.2	55	365	149
Inbred Group 4								
C 6127 . .	F 1449	191	5.10	49	2.0	0	319	181
	F 2149	208	6.50	5	2.1	0	287	132
Inbred Group 5								
C 6286 . .	F 1465	188	4.55	45	1.5	0	325	123
Inbred Group 7								
C 8079 . .	F 1589	189	5.30	22	1.8	0	365	206
	F 2147	245	6.60	23	1.6	0	252	151

Check Group 2 — No chicks.
Inbred Group 6 — No daughters.

Since only three check daughters and five inbred daughters had complete records, the data in Table 12 are of little value. The fact does stand out that broodiness has been eliminated in large measure. All of the inbreds were low in intensity, and all were low producers. There is some evidence, among the inbreds, of increased uniformity in intensity, non-broodiness and persistency. In general, the data show that inbreeding for three years has reduced vigor, egg production, and possibly variability in characteristics affecting egg production. No particular type of inbreeding has proved superior, and only occasionally were inbred matings successful.

Crossbreeding Inbred Lines

Plan of Matings — 1926

For the matings of 1926 it was decided best to crossbreed the inbred lines among themselves and to inbreed the former check lines. The plan of matings for 1926 was as follows:

Check group consisted of three females F 7, F 525 and F 943, all coming from a cross of Station-bred stock with outside "Standard" male C 75411. These three birds were mated to their sire C 7984.

All available inbred females were divided into two pens. The first pen was mated to male F 1489 from group 7, he being from a mother-son mating and not related to any of the females used. In this pen were placed two of the original sisters C 6127 and C 6286, and pullets F 725, F 1449 and F 2149, all from a half brother-sister mating. The other pullet in this pen was F 1465 from mother-son mating, not related to male F 1489.

The second pen of inbreds was mated to male F 433 from a half brother-sister mating, he being inbred to foundation hen C 1124. The females used in this pen were: C 1124 a double granddam of the male; E 425 whose pedigree showed her mother to be inbred but not related to her sire and E 425 was not related to male F 433; F 1340 not inbred and not related to male F 433; three sisters, F 1488, F 1589 and F 2147, from a mother-son mating and not related to male F 433. The results of inbreeding the checks and of crossing the inbred lines may be studied in the following tables:

TABLE 13. — CHARACTER OF FEMALE BREEDERS — 1926

Bird No.	Age at First Egg	Weight at First Egg	Pause	Average Winter Clutch	Total Days Broody	Annual Persistency	Annual Production	1926 Hatchability	Offspring
	Days	*Lbs.*	*Days*	*Eggs*	*Days*	*Days*	*Eggs*	*%*	*No.*
				Check Pen — Inbred					
F 7	206	6.45	65	1.3	0	346	124	45	4
F 525	193	5.78	41	2.6	0	352	205	71	13
F 943	167	5.20	65	2.2	55	365	149	64	7
				Inbred Pen 1 — Crossed					
C 6127	161	5.31	40	1.9	0	356	166	100	13
F 725	184	5.32	80	1.3	–	–	–	100	6
F 1449	191	5.10	49	2.0	0	319	181	65	17
F 2149	208	6.50	5	2.1	0	287	132	All infertile	
C 6286	168	5.31	20	3.3	0	350	226	50	1
F 1465	188	4.55	45	1.5	0	325	123	–	1
				Inbred Pen 2 — Crossed					
C 1124	176	4.81	22	4.3	13	365	238	80	4
F 1488	203	5.55	50	2.4	–	–	–	82	13
F 1589	189	5.30	22	1.8	0	365	206	88	16
F 1995	226	5.25	28	1.5	–	–	–	–	3
F 2147	245	6.60	23	1.6	0	252	151	58	17

The three check birds, available for mating to their sire in 1926, may be considered rather inferior in several ways. They did show early sexual maturity and satisfactory body weight, but were very inferior in winter pause and one was broody. All were genetically highly persistent, but low intensity made them inferior layers. Their hatching records fell below average also.

Inbred pen 1 was made up entirely of early maturing females and their weight at first egg was satisfactory. All but one showed a pronounced winter pause and only one carried high intensity. All were free from broodiness in the pullet year, and all but one were highly persistent. In annual egg production the pen was mediocre and only slightly superior to the check pen. Two birds in this pen showed 100 per cent hatchability, but the others were inferior. The number of chicks produced by each hen was rather small for an eight-week hatching period.

Inbred pen 2 had two late maturing birds, and mean weights were comparable with pen 1. All carried winter pause, and only one had high intensity. In non-broodiness the group ranked well and also in persistency. The production records of these dams excelled that of pen 1, and they showed more consistent high hatchability. The numbers of offspring from this pen were rather limited also.

Results of Matings — 1926

Sex ratios in surviving progeny were not far from equality. From all three pens there was produced a slight excess of males, but numbers were small so that deductions are unsafe. Complete mortality and weight records on these progeny are given in Table 14.

TABLE 14.— HATCHING RECORDS OF MOTHERS, WITH WEIGHT AND MORTALITY RECORDS OF THEIR SURVIVING PROGENY — 1926

Group Number	Dam Number	Weight of Eggs Hatched	Hatchability	Off-spring		Hatching Weight		Two-week Weight		Four-week Weight		150-day Weight		Weight at First Egg	Mortality		Weight At One Year	
				♂	♀	♂	♀	♂	♀	♂	♀	♂	♀		To Sept. 1	In Laying House	♂	♀
		Grams	%	*No.*		*Grams*		*Pounds*		*Pounds*		*Pounds*		*Pounds*	%	%	*Pounds*	
Check Pen	F 7	70.3	45	3	0	46	–	.30	–	.69	–	5.45	–	–	25	–	7.70	–
	F 525	59.9	71	6	5	41	39	.22	.18	.53	.43	5.29	3.93	5.28	15	40	7.45	5.08
	F 943	56.0	64	3	2	35	35	.19	.21	.45	.55	5.36	4.64	5.23	29	50	–	5.58
Average — check pen		**62.1**	**60**			**41**	**37**	**.24**	**.20**	**.56**	**.49**	**5.35**	**4.29**	**5.26**	**23.0**	**45.0**	**7.58**	**5.33**
Inbred Pen 1.	C 6127	63.6	100	9	3	41	41	.27	.23	.62	.50	5.75	4.65	6.11	8	0	8.29	7.15
	F 725	59.7	100	1	4	37	37	.13	.17	.42	.43	5.56	4.54	5.93	17	75	–	6.27
	F 1449	53.0	65	7	9	32	33	.16	.16	.39	.43	5.23	4.37	5.80	6	22	8.15	5.93
	C 6286	60.0	50	0	1	–	38	–	.31	–	.65	–	4.57	5.83	0	0	–	6.45
	F 1465	–	–	1	0	35	–	.20	–	.55	–	–	–	–	–	–	–	–
Average inbred pen 1		**59.3**	**79**			**38**	**37**	**.19**	**.22**	**.50**	**.50**	**5.51**	**4.53**	**5.92**	**7.8**	**24.2**	**8.23**	**6.45**
Inbred Pen 2.	C 1124	49.0	80	4	0	33	–	.16	–	37	–	4.09	–	–	0	–	6.20	–
	F 1488	52.5	82	3	4	34	35	.14	.14	.36	.37	6.16	4.24	5.60	46	25	–	6.94
	F 1589	58.6	88	4	2	38	36	.17	.14	.44	.36	5.24	4.34	5.12	63	0	7.20	5.13
	F 1995	56.0	–	3	0	39	–	.20	–	.51	–	4.90	–	–	0	–	–	–
	F 2147	61.6	58	3	9	36	38	.25	.17	.65	.41	6.01	4.46	5.96	29	29	–	6.46
Average inbred pen 2		**55.5**	**77**			**36**	**36**	**.18**	**.15**	**.47**	**.38**	**5.28**	**4.35**	**5.56**	**27.6**	**18.0**	**6.70**	**6.08**

Table 14 indicates that the check birds laid slightly heavier eggs which produced heavier chicks than the inbreds. The most significant point brought out by this table is the fact that chick mortality rate increased in the check group under inbreeding, and that chick mortality was decreased in one inbred pen by crossing. Three hens in the inbred pens gave no chick mortality to September first, and two others gave 6 and 8 per cent, respectively. Four of the hens in the inbred pens did give excessive chick mortality which would indicate that vigor was low even when inbred strains were intercrossed. Hen C 1124 gave no chick mortality when mated to her son as shown in the table.

Progeny records for one year as given in Table 14 showed a higher mortality rate in the laying houses for the original check pen when inbred than when outbred in previous years. The mortality rate of the check pullets in the laying houses was also significantly heavier than for the inbred strains crossed together in 1926. Numbers were small, however, so that too much weight should not be attached to these results.

Table 15. — Record of All Surviving Daughters from the 1926 Matings

Dam No.	Bird No.	Age at First Egg	Weight at First Egg	Pause	Average Winter Clutch	Total Days Broody	Annual Persistency	Annual Production
		Days	*Lbs.*	*Days*	*Eggs*	*Days*	*Days*	*Eggs*
			Check Pen — Inbred					
F 525	G 418	169	5.15	0	2.0	0	357	206
	G 1626	239	5.60	13	1.7	0	198	134
F 943	G 601	191	6.30	32	2.4	13	323	181
			Inbred Pen 1 — Crossed					
C 6127	G 311	186	6.37	52	1.9	0	357	201
F 725	G 1745	194	5.78	10	1.9	0	353	212
F 1449	G 740	194	5.55	30	2.0	0	223	130
	G 741	183	5.30	63	2.0	0	253	135
	G 1183	216	6.25	32	1.3	0	229	101
	G 1184	185	5.72	0	1.9	0	357	234
	G 1817	199	6.00	12	1.7	0	327	201
C 6286	G 1418	178	5.83	38	1.3	12	320	142
			Inbred Pen 2 — Crossed					
F 1488	G 1218	198	5.55	0	3.0	0	345	224
	G 1219	191	5.70	25	2.5	0	226	190
	G 1221	186	5.45	0	3.2	0	251	174
F 1589	G 1241	184	5.57	9	2.1	0	365	237
	G 1242	184	4.67	58	1.9	0	365	181
F 2147	G 372	189	6.08	53	1.6	42	344	167
	G 764	217	5.40	0	2.0	14	315	205
	G 766	216	5.80	5	1.9	14	250	141
	G 768	206	6.45	46	1.4	0	278	147
	G 1331	153	6.15	38	1.4	0	357	171

The progeny test of the matings of 1926 is recorded in Table 15. Unfortunately the number of offspring is small. The data appear to indicate greater uniformity in age at first egg for daughters from the inbred pen than from the check pen. Genetic early maturity seemed very well established in the daughters. Body weight at first egg was above breed requirements but lacked uniformity in all of the pens. Winter pause was more prolonged in the inbred daughters, and there were only four of them lacking this undesirable trait. In clutch size every daughter but two of the inbreds was deficient. It may be said that in this experiment a strain of low intensity has been established. These daughters also exhibited a low degree of broodiness. Even in the check pen broodiness was practically eliminated. The first inbred pen showed 5 daughters high in persistency to 3 low in persistency, and the second inbred pen showed 6 high to 4 low. These daughters therefore ran lower in persistency than the first generation of inbred daughters hatched in 1923. The three check daughters of 1926 showed improved persistency over 1923 (see Table 14). Annual egg records for the check daughters averaged 174 in 1926 as compared with 149 in 1923. The check group was less variable in annual production, and the inbred pens exhibited no change. In general, it may be said that crossbreeding these inbred strains did not result favorably in 1926.

Plan of Matings — 1927

Original check groups were again inbred in 1927. The check pen carried male G 417 from a sire-on-daughter mating and related to his mates. The females in this pen consisted of F 7, a half sister to male G 417 and F 525, his mother. Females G 601 and G 1321 were sired by the father of male G 417 mated to a full sister of the mother of male G 417. The other birds in this pen were G 418, G 1351, G 1352, G 1626 and G 1627, all full sisters to male G 417. This pen, therefore, represented a very high degree of inbreeding of the original check groups.

Inbred pen 1 was made up of eleven females mated to male G 315. This male was not inbred but came from one of the inbred strains. The hens in the pen consisted of C 6127, one of the original sisters in the inbreeding experiment; F 1449, a full sister to the sire of male G 315; three sisters, G 311, G 911 and G 2016, that are also half sisters to male G 315; and six sisters, G 739, G 1183, G 1184, G 1738, G 1739 and G 1817, that are also half sisters to male G 315.

Inbred pen 2 consisted of ten females mated to male F 433. Male F 433 came from a half brother-sister mating tracing directly to foundation hen C 1124. The females in the pen were: C 1124, double granddam of male F 433; F 1489 and F 2147, sisters from son-mother mating but not related to male F 433; five sisters, G 372, G 373, G 764, G 766 and G 768, not inbred but all daughters of male F 433; G 1241 and G 1242, sisters whose mother was a full sister to the dam of the preceding five hens and whose sire was male F 433.

Inbred pen 3 included seven females all mated to male G 624, a brother to male G 417 from a sire-on-daughter mating. The females consisted of three sisters, G 724, G 1219, and G 1221, also not inbred or related to male G 417; G 1418, neither inbred nor related to male G 417; and two sisters, G 1672 and G1745, not inbred and not related to male G 624.

TABLE 16.— CHARACTER OF FEMALE BREEDERS — 1927

Bird No.	Age at First Egg	Weight at First Egg	Pause	Average Winter Clutch	Total Days Broody	Annual Persistency	Annual Production	1927 Hatchability	Offspring
	Days	*Lbs.*	*Days*	*Eggs*	*Days*	*Days*	*Eggs*	*%*	*No.*
Check Pen — Inbred									
F 7	206	6.45	65	1.3	0	346	124	52	15
F 525	193	5.78	41	2.6	0	352	205	59	20
G 418	169	5.15	0	2.0	0	357	206	31	11
G 601	191	6.30	32	2.4	13	323	181	83	35
G 1321	144	4.15	–	–	Sick	–	–	26	7
G 1351	206	5.25	23	2.7	–	–	–	84	36
G 1352	323	–	–	–	–	–	–	90	9
G 1626	239	5.60	13	1.7	0	198	134	77	30
G 1627	236	5.11	19	1.2	–	–	–	85	29
Inbred Pen 1 — Crossed									
C 6127	161	5.31	40	1.9	0	356	166	39	7
F 1449	191	5.10	49	2.0	0	319	181	70	31
G 311	186	6.37	52	1.9	0	357	201	24	6
G 739	217	5.05	38	1.7	–	–	–	11	3
G 911	166	5.57	–	–	Sick	–	–	36	15
G 1183	216	6.25	32	1.3	0	229	101	5	1
G 1184	185	5.72	0	1.9	0	357	234	26	10
G 1738	196	5.87	29	1.5	–	–	–	20	8
G 1739	215	6.40	25	1.4	–	–	–	13	5
G 1817	199	6.00	12	1.7	0	327	201	13	4
G 2016	220	6.40	17	1.4	–	–	–	19	8
Inbred Pen 2 — Crossed									
C 1124	176	4.81	22	4.3	13	365	238	0	–
F 1589	189	5.30	22	1.8	0	365	206	71	31
F 2147	245	6.60	23	1.6	0	252	151	72	29
G 372	189	6.08	53	1.6	42	344	167	20	4
G 373	331	–	–	–	–	–	–	5	2
G 764	217	5.40	0	2.0	14	315	205	52	23
G 766	216	5.80	5	1.9	14	250	141	89	16
G 768	206	6.45	46	1.4	0	278	147	7	2
G 1241	184	5.57	9	2.1	0	365	237	80	12
G 1242	184	4.67	58	1.9	0	365	181	All infertile	
Inbred Pen 3 — Crossed									
G 724	195	5.70	5	2.0	–	–	–	68	28
G 1219	191	5.70	25	2.5	0	226	190	44	18
G 1221	186	5.45	0	3.2	0	251	174	75	24
G 1418	178	5.83	38	1.3	12	320	142	35	14
G 1672	190	5.25	4	2.2	–	–	–	All infertile	
G 1745	194	5.78	10	1.9	0	353	212	13	6

Table 16 does not show any striking differences in the characteristics of the female breeders used in the check pen as compared with those used in the inbred pens. This fact is further brought out by their annual egg records which depend very largely upon the traits tabulated above (Hays and Sanborn, 1927). If significant differences occur in the character of progeny produced by the four pens, such must be ascribed either to genetic differences in the male parents or to inbreeding.

Results of Matings — 1927

Inbreeding affected the sex ratio of surviving chicks.

The plan of matings for 1927 shows that the check-pen offspring represented a rather high degree of inbreeding, that inbred pen 1 progeny were almost entirely from half brother-sister matings, that inbred pen 2 progeny came largely from sire-on-daughter matings and inbred pen 3 progeny represented crosses of inbred lines.

Check pen progeny showed the low sex ratio in surviving chicks that has been previously referred to in this report as possibly associated with close inbreeding. Inbred pen 1 showed a high sex ratio even though the chicks came largely from half-brother-sister matings. Inbred pen 2, with progeny largely from sire-on-daughter matings, gave equality of sexes. In inbred pen 3 where inbred lines were crossed there occurred a low sex ratio which has been characteristic of close inbreeding.

These data appear to indicate that inbred male chicks are less able to survive than are female chicks. Such a difference probably arises from more vicious fighting among males than among females. Inbred males are probably less vigorous than ordinary production-bred males with which they run and many succumb in the struggle.

TABLE 17.— HATCHING RECORDS OF MOTHERS, WITH WEIGHT AND MORTALITY RECORDS OF THEIR SURVIVING PROGENY — 1927

Group Number	Dam Number	Weight of Eggs Hatched	Hatchability	Offspring		Hatching Weight		Two-week Weight		Four-week Weight		150-day Weight		Weight at First Egg	Mortality		Weight at One Year	
				♂	♀	♂	♀	♂	♀	♂	♀	♂	♀		To Sept. 1	In Laying House	♂	♀
		Grams	%	*No.*		*Grams*		*Pounds*		*Pounds*		*Pounds*		*Pounds*	%	%	*Pounds*	
Check Pen	F 7	73.2	52	7	6	48	44	.25	.23	.56	.53	5.36	4.30	5.48	13	40	6.70	5.42
	F 525	62.5	59	6	12	38	39	.18	.18	.40	.37	4.59	3.83	5.00	10	40	7.40	5.03
	G 418	62.6	31	2	7	40	40	.14	.16	.35	.31	–	4.12	5.47	27	0	–	5.60
	G 601	60.1	83	12	16	37	36	.18	.17	.41	.37	5.27	4.24	5.43	26	29	–	5.89
	G 1321	53.7	26	1	0	35	–	.20	–	.44	–	4.47	–	–	86	–	–	–
	G 1351	53.6	84	2	12	35	32	.16	.15	.45	.35	5.55	3.69	–	64	–	–	–
	G 1352	56.2	90	4	4	35	36	.15	.16	.28	.31	3.82	3.33	–	11	–	–	–
	G 1626	56.8	77	9	11	37	37	.17	.16	.36	.33	5.34	3.68	–	40	–	–	–
	G 1627	58.1	85	11	9	35	36	.21	.16	.38	.31	4.87	3.78	4.94	31	44	–	5.18
Average check pen		**59.6**	**65**			**38**	**38**	**.18**	**.17**	**.40**	**.36**	**4.91**	**3.87**	**5.26**	**34.2**	**30.6**	**7.05**	**5.42**
Inbred Pen 1	C 6127	63.1	39	5	1	39	44	.21	.22	.43	.51	5.19	4.36	–	14	–	–	–
	F 1449	53.9	70	12	10	32	31	.18	.19	.42	.39	5.24	4.24	5.52	32	10	8.00	5.92
	G 311	57.5	24	1	3	37	31	.19	.20	.49	.43	4.88	4.03	–	50	–	–	–
	G 739	58.7	11	1	1	33	36	13	.19	.27	.26	–	2.90	–	33	–	–	–
	G 911	55.2	36	7	3	34	37	.18	.17	.37	.37	4.62	3.59	–	40	–	–	–
	G 1183	57.0	5	1	0	36	–	.18	–	.28	–	–	–	–	0	–	–	–
	G 1184	62.6	26	4	5	36	37	.22	.20	.48	.42	4.52	4.27	5.81	20	0	–	5.70
	G 1738	54.4	20	3	5	33	32	.20	.21	.42	.38	5.76	3.70	5.51	0	40	–	5.51
	G 1739	56.5	13	5	0	32	–	.17	–	.35	–	–	–	–	0	–	–	–
	G 1817	58.0	13	1	1	33	33	.21	.19	.50	.44	–	4.26	5.50	50	0	–	5.90
	G 2016	64.0	19	5	0	38	–	.19	–	.41	–	4.64	–	–	38	–	–	–
Average inbred pen 1		**58.3**	**25**			**35**	**36**	**.19**	**.20**	**.40**	**.40**	**4.98**	**3.92**	**5.59**	**25.2**	**12.5**	**8.00**	**5.76**
Inbred Pen 2	F 1589	61.3	71	12	14	36	36	.22	.20	.47	.43	5.92	4.45	5.32	16	31	8.61	5.84
	F 2147	60.1	72	10	17	36	35	.21	.20	.45	.44	6.03	4.79	6.00	7	14	8.55	7.17
	G 372	56.5	20	4	0	32	–	.16	–	.36	–	–	–	–	25	–	–	–
	G 373	59.0	5	1	0	32	–	.21	–	.47	–	–	–	–	100	–	–	–
	G 764	55.5	52	5	6	33	33	.19	.18	.40	.37	5.27	3.94	–	48	–	–	–
	G 766	54.6	89	6	6	33	32	15	.14	.34	.37	4.33	3.62	–	38	–	–	–
	G 1241	58.1	80	8	4	37	36	.14	.15	.31	.32	4.25	3.95	5.36	8	75	7.55	5.93
Average inbred pen 2		**57.9**	**42**			**34**	**34**	**.18**	**.17**	**.40**	**.37**	**5.16**	**4.15**	**5.56**	**34.6**	**40.0**	**8.24**	**6.31**
Inbred Pen 3	G 724	54.1	68	4	9	29	31	.17	.16	.39	.35	6.02	4.10	–	54	–	–	–
	G 1219	54.1	44	8	3	31	31	.14	.14	.28	.25	5.66	3.67	–	39	–	–	–
	G 1221	57.0	75	5	7	34	34	.22	.19	.45	.40	6.22	4.11	5.33	50	0	7.52	5.69
	G 1418	60.4	35	2	11	37	38	.18	.20	.39	.44	–	4.41	5.59	7	13	–	5.91
	G 1745	58.0	13	2	1	36	35	.14	.22	.42	.45	–	4.54	–	50	–	–	–
Average inbred pen 3		**56.7**	**47**			**33**	**34**	**.17**	**.18**	**.39**	**.38**	**5.97**	**4.17**	**5.46**	**40.0**	**6.5**	**7.52**	**5.80**

The check pen was superior to the three inbred pens in mean weight of eggs hatched and in hatching weight of chicks. In the percentage of fertile eggs hatched, the check pen surpassed the others. Inbred pen 1 with progeny from half brother-sister matings was superior to any other pen in vigor of chicks. There were three families from this pen with no mortality up to September first, while not a single family in the other pens was free from mortality during this period. The fact should be noted that inbred pen 3 where the inbred lines were crossed had a slightly greater chick mortality than the other pens.

Progeny weight records for one year show that the pullets descending from the original check group after this group was closely inbred were smaller at first egg than the pullets of the inbred groups. The same situation also existed for both males and females at one year of age.

The mortality rate for pullets in the laying houses was very significantly greater in the check group than in either inbred groups 1 or 3. The daughters from inbred pen 2, largely from sire-on-daughter matings, showed a mortality rate somewhat greater than occurred in the check daughters. Possibly on the whole the check daughters were less vigorous than the inbred daughters.

TABLE 18.— RECORD OF ALL SURVIVING DAUGHTERS FROM THE 1927 MATINGS

Dam No.	Bird No.	Age at First Egg	Weight at First Egg	Pause	Average Winter Clutch	Total Days Broody	Annual Persistency	Annual Production
		Days	*Lbs.*	*Days*	*Eggs*	*Days*	*Days*	*Eggs*
				Check Pen — Inbred				
F 7	H 706	188	5.43	52	1.3	0	256	103
	H 2968	204	5.35	0	2.1	0	308	173
F 525	H 2091	199	4.67	34	1.7	0	310	159
	H 2476	214	5.65	21	1.6	0	270	141
	H 2951	210	5.88	0	1.8	0	312	160
G 418	H 2151	215	5.35	17	1.9	32	237	131
	H 2687	196	5.38	0	1.9	0	350	170
	H 2688	187	5.40	0	2.8	0	310	153
	H 2689	201	5.60	4	1.9	0	342	188
	H 3201	200	4.44	25	1.5	0	354	161
G 601	H 222	177	5.75	42	1.9	0	337	149
	H 225	156	4.65	41	2.8	0	317	149
	H 745	151	5.06	63	1.8	0	295	136
	H 1265	179	5.48	39	2.3	0	349	185
	H 1268	184	5.72	4	2.0	0	366	193
	H 1766	221	5.75	0	2.9	0	333	225
	H 2162	165	4.59	34	1.6	0	366	190
	H 2163	198	5.80	20	2.4	0	292	175
	H 2165	209	5.25	14	1.6	9	278	132
G 1627	H 2839	209	4.30	18	1.8	0	339	168
	H 3290	193	4.52	0	1.8	0	281	165
	H 3292	199	5.55	22	2.3	0	270	157
				Inbred Pen 1 — Crossed				
F 1449	H 235	175	5.10	42	3.5	48	364	220
	H 830	169	5.10	4	3.1	0	314	211
	H 1140	164	5.35	29	1.8	0	366	208
	H 1564	175	4.68	43	2.2	0	319	121
	H 2513	213	6.05	21	3.0	0	342	215
	H 3062	212	5.12	32	1.9	0	331	180
	H 3063	184	5.40	26	3.5	28	366	209
	H 3064	203	5.85	12	2.5	20	366	219
G 1184	H 2791	212	5.60	0	3.6	0	362	215
	H 2792	204	5.58	6	2.0	0	300	163
	H 3379	221	6.42	0	3.5	0	335	187
G 1738	H 1856	228	5.10	22	1.9	0	329	194
	H 2832	187	5.77	0	2.2	0	366	209
G 1817	H 3325	203	5.50	40	1.9	0	309	158

Table 18.— Record of All Surviving Daughters from the 1927 Matings — Concluded

Dam No.	Bird No.	Age at First Egg	Weight at First Egg	Pause	Average Winter Clutch	Total Days Broody	Annual Persistency	Annual Production
		Days	*Lbs.*	*Days*	*Eggs*	*Days*	*Days*	*Eggs*
Inbred Pen 2 — Crossed								
F 1589	H 608	160	5.10	51	4.4	0	248	154
	H 1621	174	5.01	22	2.7	0	366	212
	H 2328	151	4.60	50	2.6	19	366	205
	H 2586	209	5.65	18	2.4	0	366	228
	H 2587	197	5.70	20	2.5	17	361	206
	H 2588	198	5.60	58	2.8	20	366	193
	H 2589	193	6.37	0	2.7	0	324	223
	H 3014	217	5.00	7	2.4	0	331	224
	H 3557	167	4.82	0	4.3	43	356	219
F 2147	H 314	159	5.20	0	2.8	11	366	246
	H 319	165	5.88	47	2.6	0	366	182
	H 601	172	5.50	15	1.7	0	366	182
	H 602	174	5.30	22	2.2	19	366	228
	H 1100	176	6.03	48	1.9	0	331	160
	H 1711	164	5.59	10	3.0	0	366	226
	H 1712	178	5.66	12	2.2	0	366	199
	H 2172	179	6.71	25	2.4	22	342	197
	H 2599	214	6.78	20	2.1	18	307	145
	H 3054	187	6.47	19	2.3	18	366	220
	H 3055	213	7.15	0	1.8	17	299	169
	H 3056	169	5.87	21	2.1	11	366	194
G 1241	H 2267	215	5.66	21	1.8	0	366	185
Inbred Pen 3 — Crossed								
G 1221	H 60	261	5.48	0	5.2	0	178	142
	H 2802	199	5.05	0	2.8	0	366	202
	H 2804	166	4.93	19	2.6	0	366	181
	H 3244	173	5.37	0	2.7	30	366	216
	H 3246	199	5.77	0	3.4	0	330	228
	H 3247	173	5.74	4	3.6	0	366	211
G 1418	H 101	168	6.00	82	2.2	0	366	193
	H 2248	184	6.05	0	4.1	0	366	237
	H 2774	169	4.77	33	3.6	0	233	203
	H 3192	179	5.58	0	2.8	0	366	221
	H 3193	226	5.10	0	2.8	0	334	216
	H 3194	204	5.90	9	4.1	24	366	254
	H 3195	205	5.45	0	2.6	0	174	155

Table 18 shows the progeny records from the 1927 matings. In the check daughters under the second generation of inbreeding, early sexual maturity was well established. This group of daughters was, however, significantly lighter in weight at first egg than the inbred daughters. Winter pause was more common in the check daughters than in inbred daughters from pen 3. Check daughters were very deficient in intensity. The majority showed small clutch size, and they were inferior to all of the inbred groups in this respect. Broodiness during the pullet year had almost disappeared in the checks. Lack of high persistency was notable in the check daughters. They showed about equal numbers with high and low persistency, while the inbreds showed a much greater proportion with high persistency. As might be anticipated, the annual egg records of the check daughters fell far below the records of the inbreds.

The three inbred pens may be cited as examples of results from different degrees of inbreeding. Inbred pen 1 daughters, coming from half brother-sister matings of the original inbreds, were satisfactory in early maturity and in body weight. This group of daughters showed 3 non-pause to 11 pause, and less than half were high for intensity. From the standpoint of non-broodiness, they were satisfactory, there being 11 non-broody to 3 broody. In persistency the proportions were 11 high to 3 low. The mean annual egg record for pen 1 was not satisfactory, largely because of low intensity in more than half of the daughters.

Inbred pen 2 was made up largely of daughters from father-daughter matings. The character of the mothers of these birds did not differ greatly from the mothers used in pen 1. Table 18 shows the daughters from pen 2 to be somewhat superior to those from pen 1 chiefly in body weight, persistency and annual egg record. Their high mean annual egg record was due largely to the nine daughters of hen F 1589 that averaged 207 eggs. These appear first in Table 18 and are followed by the 12 daughters of F 2147, her full sister. These two dams were both inbred but not related to their inbred mate used in 1927. This type of mating gave significant uniformity in the traits being studied in the daughters of F 1589 but not in the daughters of her sister F 2147.

Inbred pen 3 daughters came from dams G 1221 and G 1418. The first six listed were from G 1221. The daughters from these matings did not exhibit uniformity in age at sexual maturity or in body weight. They were superior to the other groups with respect to winter pause. The two families of daughters were about equal in clutch size and in persistency. In annual egg records there was a considerable degree of uniformity. This pen indicates that in two matings out of six the crossing of inbred strains was advantageous. The offspring from other matings was not carried through the year.

Plan of Matings — 1928

In 1928 the mating pens consisted of one check pen and three of the original inbred pens. In this concluding year of the experiment it seemed desirable to attempt to discover if any possible mating combinations would be particularly advantageous from the standpoint of high fecundity. The mating pens were made up as follows:

The check pen contained male G 624, representing a sire-on-daughter mating and traced to the outside "Standard" male C 75411 that was used in the original check matings. The females used were G 418, a full sister to male G 624; G 601, half sister to male G 624 and from a sire-daughter mating; two outbred sisters, G764 and G1331, unrelated to male G 624; G 1218, not inbred and unrelated to male G 624; G 1817, not inbred or related to male G 624; and two sisters, H 224 and H 747, from half brother-sister mating and intimately related to male G 624 through his sire.

Inbred pen 1 was composed of nine females mated to male G 315. This male was not himself inbred but traced directly to C 1124. The females used were as follows: F 525 from former check group and unrelated to male G 315; hen F 1449, from a half brother-sister mating from C 1124 and distantly related to male G 315 through C 1124; F 1589, representing a sire-on-daughter mating and related to male G 315 whose grandsire is her sire; G 1184, not inbred but a half sister to male G 315; G 1241, a full sister to male G 315; G 1626. from a sire-on-daughter mating but unrelated to male G 315; G 1745, not inbred but almost a full "blood" sister to male G 315; two sisters, H 2687 and H2688, from full brother-sister matings but not related to male G 315.

Inbred pen 2 was made up of seven females mated to male G 1965. This male came from mating male F 433 that was inbred to hen C 1124, back to hen C 1124. He therefore represents distinct inbreeding to foundation hen C 1124. The females in the pen were two sisters, H 314 and H 602, not inbred but carrying C 1124 in their paternal ancestry and being half sisters to male G 1965; H 2267, coming from a sire-daughter mating both tracing to C 1124, and a half sister to male G 1965; two sisters, H 2774 and H 3192, not inbred but tracing to C 1124 on their dam's side and but remotely related to male G 1965 through C 1124:

and two sisters, H 2802 and H 3246, granddaughters of F 433 but not inbred though related to male G 1965.

Inbred pen 3 included eight females mated to male H 317. This male was outbred but traced to hen C 1124, as his only paternal greatgranddam. The females used were three sisters, H 1565, H 3063 and H 3064, which traced to C 1124 in the third generation on both sides of their pedigree; pullets H 2791 and H 2792, full sisters which trace to C 1124 in the fourth generation; sisters H 1854 and H 1856, carrying the same relationship to C 1124 as the two pullets just mentioned and differing only in that their dam was a full sister to the dam of the two pullets in question; pullet H 2151 from a full brother-sister mating, but unrelated to male H 317.

TABLE 19. — CHARACTER OF FEMALE BREEDERS — 1928

Bird No.	Age at First Egg	Weight at First Egg	Pause	Average Winter Clutch	Total Days Broody	Annual Persistency	Annual Production	1928 Hatchability	Offspring
	Days	*Lbs.*	*Days*	*Eggs*	*Days*	*Days*	*Eggs*	*%*	*No.*
Check Pen — Inbred									
G 418	169	5.15	0	2.0	0	357	206	29	2
G 601	191	6.30	32	2.4	13	323	181	50	16
G 764	217	5.40	0	2.0	14	315	205	95	37
G 1218	198	5.55	0	3.0	0	345	224	87	20
G 1331	153	6.15	38	1.4	0	357	171	70	14
G 1817	199	6.00	12	1.7	0	327	201	40	6
H 224	207	5.76	0	1.8	–	–	–	79	11
H 747	195	5.09	0	2.2	–	–	–	33	0
Inbred Pen 1 — Crossed									
F 525	193	5.78	41	2.6	0	352	205	100	25
F 1449	191	5.10	49	2.0	0	319	181	83	19
F 1589	189	5.30	22	1.8	0	365	206	45	5
G 1184	185	5.72	0	1.9	0	357	234	36	8
G 1241	184	5.57	9	2.1	0	365	237	62	8
G 1626	239	5.60	13	1.7	0	198	134	–	0
G 1745	194	5.78	10	1.9	0	353	212	46	12
H 2687	196	5.38	0	1.9	0	350	170	74	20
H 2688	187	5.40	0	2.8	0	310	153	0	0
Inbred Pen 2 — Crossed									
H 314	159	5.20	0	2.8	11	366	246	78	31
H 602	174	5.30	22	2.2	19	366	228	87	20
H 2267	215	5.66	21	1.8	0	366	185	0	0
H 2774	169	4.77	33	3.6	0	233	203	100	10
H 2802	199	5.05	0	2.8	0	366	202	–	0
H 3192	179	5.58	0	2.8	0	366	221	17	0
H 3246	199	5.77	0	3.4	0	330	228	17	0
Inbred Pen 3 — Crossed									
H 1565	185	5.80	37	2.0	–	–	–	10	0
H 3063	184	5.40	26	3.5	28	366	209	72	31
H 3064	203	5.85	12	2.5	20	366	219	28	0
H 2791	212	5.60	0	3.6	0	362	215	46	18
H 2792	204	5.58	6	2.0	0	300	163	13	0
H 1854	229	5.62	8	3.0	–	–	–	0	0
H 1856	228	5.10	22	1.9	0	329	194	59	19
H 2151	215	5.35	17	1.9	32	237	131	84	27

The check pen females used as breeders in 1928 were all early maturing but one. They all showed satisfactory weight but there was a wide variation in weight. Five of these birds lacked winter pause to three showing winter pause. There was but one of the eight high for intensity. Two of the group were broody as pullets, and one had an incomplete record. In persistency all were genetically high as shown by the ability to lay for not less than 315 days before going into complete molt. Their annual egg records were moderately high and fairly uniform. The hatching records of these pens were comparable with those of the inbred pens, there being 2 genetically high, 2 medium and 4 low (Hays and Sanborn, 1924).

Practically all of the birds in the three inbred pens traced to foundation hen C 1124. Her line of inbreds was the only survivors of the original inbreds as the plan of matings for 1928 shows. Pen 2 females were superior to those of pen 1 or pen 3, particularly from the standpoint of intensity and annual egg production. Pen 2 did show more broodiness, however, than pen 1, but less broodiness than pen 3. Inbred pens 1 and 3 were very similar in the characteristics being considered. The two pens appeared to differ only in amount of broodiness and slightly in persistency. Their mean annual egg records were almost identical. These two pens really represented descendants of foundation hen C 1124, and pen 2 represented a more intimate concentration of the heritage from C 1124.

Results of Matings — 1928

The sex ratios on surviving chicks were slightly lower in the three original inbred pens after intercrossing than in the original check pen under inbreeding. The ratio was 95 males to 100 females in the first group compared with 102 males to 100 females in the second group.

TABLE 20.— HATCHING RECORDS OF MOTHERS, WITH WEIGHT AND MORTALITY RECORDS OF THEIR SURVIVING PROGENY TO MARCH 1 — 1928

Group Number	Dam Number	Weight of Eggs Hatched	Hatchability	Offspring		Hatching Weight		Two-week Weight		Four-week Weight		150-day Weight		Mortality to Sept. 1	Weight at First Egg
				♂	♀	♂	♀	♂	♀	♂	♀	♂	♀		
		Grams	%	*No.*		*Grams*		*Pounds*		*Pounds*		*Pounds*		%	*Pounds*
Check Pen	G 418	84.5	29	0	2	–	48	–	.21	–	.36	–	4.94	0	–
	G 601	61.6	50	5	8	49	40	.18	.20	.40	.41	4.91	4.30	19	5.44
	G 764	58.7	95	17	17	35	34	.19	.19	.40	.39	5.37	4.07	14	5.59
	G 1218	57.3	87	13	6	34	32	.19	.15	.43	.31	5.69	4.16	10	5.58
	G 1331	66.4	70	5	8	41	41	.23	.21	.49	.46	6.28	4.55	7	–
	G 1817	65.8	40	2	4	41	39	.23	.18	.48	.43	5.64	4.77	0	–
	H 224	62.6	79	7	3	41	41	.21	.19	.45	.41	5.05	4.12	9	–
Average check pen		**65.3**	**64**			**40**	**39**	**.21**	**.19**	**.44**	**.40**	**5.49**	**4.42**	**8.4**	**5.54**
Inbred Pen 1	F 525	60.2	100	8	13	37	39	.19	.21	.40	.40	5.36	4.14	16	5.30
	F 1449	54.7	83	6	10	32	32	.20	.19	.45	.42	5.32	3.64	16	5.28
	F 1589	62.6	45	3	0	38	–	.15	–	.39	–	3.00	–	40	–
	G 1184	69.1	36	3	3	42	41	.24	.21	.54	.44	6.19	3.89	38	5.30
	G 1241	66.0	62	4	4	43	40	.24	.23	.45	.45	5.09	4.12	0	5.05
	G 1745	66.6	46	7	3	40	41	.22	.22	.45	.47	4.93	–	17	–
	H 2687	58.3	74	9	10	37	39	.23	.22	.50	.45	6.05	4.16	5	5.28
Average inbred pen 1		**62.5**	**64**			**38**	**39**	**.21**	**.21**	**.45**	**.44**	**5.13**	**3.99**	**18.9**	**5.24**
Inbred Pen 2	H 314	59.9	78	15	12	36	36	.20	.20	.41	.42	5.28	4.17	19	5.23
	H 602	58.1	87	8	9	35	36	.19	.17	.40	.32	4.89	3.70	20	–
	H 2774	55.4	100	3	7	35	36	.21	.18	.41	.35	4.63	3.84	0	4.88
Average inbred pen 2		**57.8**	**88**			**35**	**36**	**.20**	**.18**	**.41**	**.36**	**4.93**	**3.91**	**13.0**	**5.06**
Inbred Pen 3	H 3063	55.4	72	11	14	35	34	.18	.19	.41	.40	4.81	4.07	19	–
	H 2791	54.6	46	8	4	34	33	.18	.17	.41	.30	4.45	4.08	33	–
	H 1856	61.7	59	4	9	40	38	.23	.19	.45	.37	5.31	4.10	32	–
	H 2151	60.7	84	12	8	39	39	.22	.22	.49	.45	5.39	4.27	30	5.40
Average inbred pen 3		**58.1**	**65**			**37**	**38**	**.20**	**.19**	**.44**	**.38**	**4.99**	**4.13**	**28.5**	**5.40**

Table 20 shows the mean weight of the eggs that actually hatched from the different females. The check pen birds all laid very large eggs and all were appreciably heavier than 56.7 grams which is considered a satisfactory weight. Inbred pen 1 also gave very large eggs with the exception of one bird whose eggs averaged but 54.7 grams. Inbred pen 2 contained one small-egg bird, and half of the females in inbred pen 3 laid small eggs.

Hatchability was low from the very large eggs. The hatching record of inbred pen 2 was superior to any of the other pens and the eggs were slightly below the other pens in mean weight. It is probable that the most satisfactory egg weight for high hatching in this flock ranges from 55 to 60 grams.

Chick mortality to September first ran highest for inbred pens 1 and 3 and lowest for inbred pen 2. There was one female each in the check pen and in inbred pens 1 and 2 that showed no chick mortality to September first. In general, there was a slightly greater chick mortality for the inbred pens than for the check pen.

The mean numbers of chicks produced per hen in each pen were approximately equal. To the age of four weeks, there was no significant difference in mean weight in the four pens. At the four-week weight the check group of chicks were somewhat heavier than the inbreds, and this difference was increased at the age of 150 days. In mean weight of pullets at first egg, the check pullets were slightly superior as might be anticipated from the fact that they traced to heavier foundation stock than did the inbreds. The experiment was concluded March 1, 1929, so that weights at one year were not recorded.

TABLE 21.— RECORD TO MARCH 1 OF ALL SURVIVING DAUGHTERS FROM THE 1928 MATINGS

Dam Number	Bird Number	Age at First Egg	Weight at First Egg	Pause	Average Winter Clutch
		Days	*Pounds*	*Days*	*Eggs*
Check Pen — Inbred					
G 601	I 585	170	5.60	10	2.5
	I 587	233	5.80	54	2.0
	I 588	209	5.30	46	1.9
	I 1048	–	–	–	–*
	I 2170	205	4.85	5	2.1
	I 2527	198	5.65	0	2.1
G 764	I 449	179	5.42	25	5.6
	I 1072	–	–	–	–*
	I 1073	171	5.15	4	2.7
	I 1603	194	6.50	0	3.3
	I 1605	204	5.45	0	2.4
	I 2121	201	5.20	0	3.1
	I 2122	215	6.00	0	3.2
	I 2585	197	4.90	0	4.2
	I 2587	212	6.65	44	3.5
	I 3230	227	5.25	0	2.9
	I 3232	211	5.85	0	2.7
	I 3233	186	5.25	0	4.0
	I 3234	221	5.50	0	2.6
G 1218	I 532	237	5.20	0	4.4
	I 534	169	5.85	4	3.7
	I 1081	171	5.50	24	3.4
	I 2907	223	5.75	0	4.9

* No eggs.

Table 21 — Record to March 1 of all Surviving Daughters from the 1928 Matings — Concluded

Dam Number	Bird Number	Age at First Egg	Weight at First Egg	Pause	Average Winter Clutch
		Days	*Pounds*	*Days*	*Eggs*
Inbred Pen 1 — Crossed					
F 525	I 976	161	5.85	49	2.0
	I 1521	185	4.95	57	2.9
	I 1522	181	5.05	0	2.6
	I 1523	161	5.37	8	1.8
	I 1524	217	5.05	0	2.3
	I 2534	208	4.85	17	1.5
	I 2535	209	7.10	43	1.8
	I 2536	203	5.00	5	3.7
	I 2926	202	4.90	0	2.3
	I 2928	207	4.60	6	3.0
	I 3208	199	5.10	20	1.4
	I 3210	192	5.25	0	1.9
	I 3211	205	5.80	26	2.8
F 1449	I 483	180	5.03	49	1.5
	I 484	185	5.10	39	2.5
	I 485	209	5.00	40	2.2
	I 487	213	5.45	6	1.7
	I 518	228	5.05	4	1.4
	I 519	197	4.65	7	1.8
	I 1006	222	6.20	0	2.0
	I 1007	214	5.60	0	3.1
	I 1563	204	5.40	0	1.7
G 1184	I 489	211	5.55	41	2.3
	I 1638	194	5.05	39	2.1
	I 1639	206	5.30	0	2.0
G 1241	I 493	159	5.15	39	1.8
	I 494	159	4.65	25	3.0
	I 603	176	4.85	18	1.9
	I 604	234	5.55	12	1.4
H 2687	I 472	209	5.50	0	2.0
	I 474	181	5.06	53	2.2
	I 860	171	5.55	9	1.8
	I 1479	273	5.55	6	3.4
	I 1480	181	4.90	28	2.4
	I 2483	169	5.25	45	3.1
	I 2484	187	5.05	39	3.0
	I 2857	199	5.60	4	1.9
	I 3151	184	–	12	3.3
	I 3152	198	5.05	0	3.3
Inbred Pen 2 — Crossed					
H 314	I 457	176	5.11	34	2.3
	I 610	203	5.10	15	2.8
	I 1137	175	5.05	33	1.9
	I 1792	151	4.69	11	3.0
	I 2231	219	5.60	12	2.9
	I 2232	223	5.40	0	2.1
	I 2655	201	5.50	12	2.2
	I 2996	178	5.20	15	2.8
	I 2998	234	5.05	0	3.3
	I 3328	203	5.60	16	2.6
H 2774	I 2440	201	5.40	0	5.1
	I 2442	186	5.40	13	5.7
	I 2866	182	5.00	9	2.9
	I 2868	196	4.90	0	4.0
	I 2869	184	5.00	0	2.5
	I 3523	188	4.25	8	3.9
	I 3524	187	4.20	18	2.2
Inbred Pen 3 — Crossed					
H 2151	I 478	173	5.13	24	2.3
	I 940	170	5.80	30	2.6
	I 941	194	5.55	9	2.2
	I 1283	179	5.10	37	1.7
	I 2434	205	5.80	41	1.7
	I 3108	208	5.70	0	2.2
	I 3452	198	4.80	0	3.1

Table 21 supplies the daughters' records up to March 1, 1929. Only those daughters with complete records to this date are included in the table.

In the age at first egg there were 56 early-maturing and 7 late-maturing inbred daughters compared with 16 early and 5 late in the checks. This gives a ratio of 8 early to 1 late inbred and about 3 early to 1 late check. There was, therefore, a larger proportion of late-maturing birds in the check group under inbreeding.

In body weight at first egg the check pullets were superior to the inbreds. This may be due in part to heavier birds used in the ancestry of the checks and in part to a greater age for the checks at time of weighing.

In percentage of pullets free from winter pause, the check group excelled. There were 12 non-pause to 9 pause birds in the check group. In the three inbred pens there were 17 free from pause to 46 showing pause. Thus 57 per cent of the check pullets lacked pause compared with but 27 per cent free from pause in the inbreds.

From the standpoint of intensity the check pullets were superior to the inbreds. In the checks there were 15 with high intensity and 6 with low intensity, compared with 24 high and 39 low for the inbreds. Thus about three-fourths of the checks exhibited high intensity, while slightly more than half of the inbreds showed high intensity. Here again is further evidence that the surviving inbred lines were deficient in intensity and that the check line made progress in intensity even under inbreeding.

These incomplete records offer some evidence of superiority in the check group over the inbreds which may enable them to make higher annual records than the inbreds. Probably this apparent superiority in characteristics affecting fecundity in checks over inbreds is ascribable to greater diversity in the foundation stock of the checks which would prevent inbreeding from uncovering weaknesses so readily as in the narrow inbred group. There is no evidence of reduced variability in age, body weight, pause, or intensity in either the check or the inbred groups in Table 21.

Graphic Presentation of Results

A graphic presentation of the results of this inbreeding experiment is given in charts 1 to 10. Each chart gives the means of dams and resulting daughters for each year of the experiment both in the check groups and in the inbred groups. Such a series enables the reader to see at a glance just what took place in general as the experiment progressed. The charts include only mothers that actually had daughters whose records were obtained. These charts are intended only to present a composite picture of results. They are in no sense a duplication of the data already presented and they are of no value for genetic analysis.

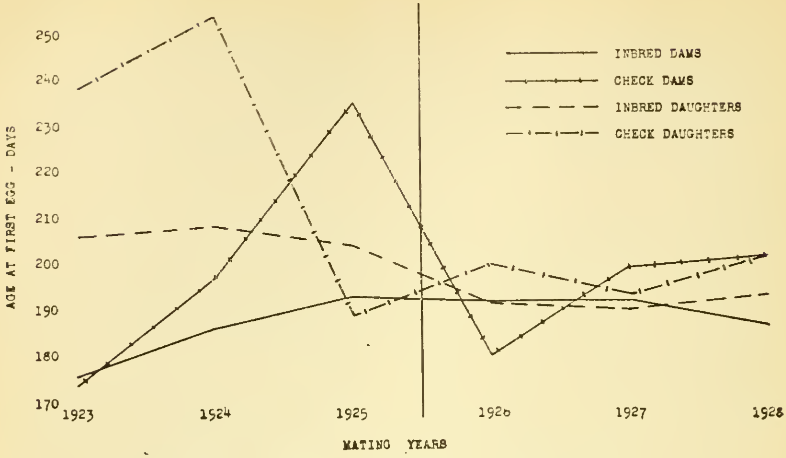

CHART 1.—Effect of Inbreeding on Sexual Maturity

Chart 1 shows how age at sexual maturity behaved. The fact will be noted that both inbred dams and check dams were of the same age, about 176 days, at first egg in 1923. In 1924 the age for inbred dams increased to 186 days, while the check dams increased to 197 days. In 1925 inbred dams were 193 days old and check dams were 235 days old when they laid their first egg. The daughters from the dams in the inbred group showed a mean age of 206 days in 1923, 208 days in 1924, and 204 days in 1925. Inbreeding apparently did not affect the mean age of daughters. The check daughters of 1923 averaged 238 days; those of 1924, 254 days; and those of 1925, 189 days. Early sexual maturity in the three check daughters for 1925 came from their sire, C 7984, that came from the production-bred strain, and he transmitted the dominant genes for early maturity to his daughters.

During the last three years of the experiment, when the checks were inbred and the inbred strains intercrossed, all dams and all daughters in both groups averaged 200 days or less at first egg. This places them in the class of genetically early maturing birds. On the whole, chart 1 does not indicate for this experiment that inbreeding affected age at sexual maturity.

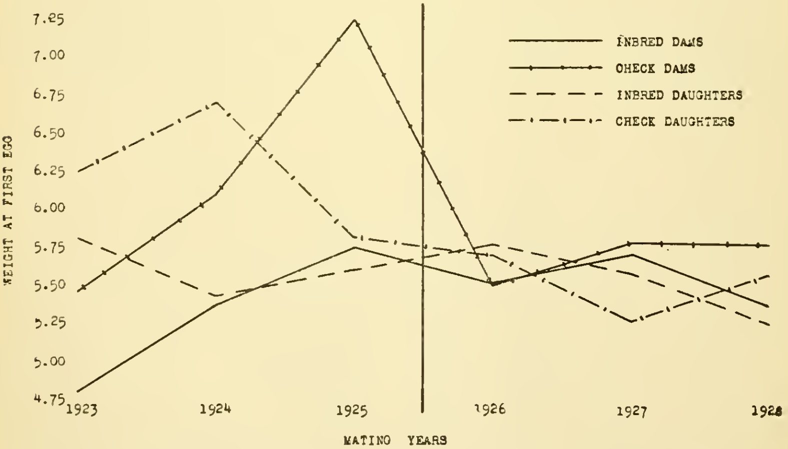

CHART 2.—Effect of Inbreeding on Weight at First Egg. (Weight in Pounds)

In body weight at first egg the inbred mothers increased from the initial mean of 4.81 pounds to 5.72 pounds in 1925. The check mothers began with a mean weight of 5.45 pounds and increased to a mean of 7.24 pounds in 1925. The inbred daughters averaged 5.81 pounds the first year, and their average was 5.61 pounds in 1925. The check daughters averaged 6.23 pounds in 1923, 6.68 pounds in 1924, and 5.81 pounds in 1925. The chart therefore indicates that even though the mean weight of mothers selected each year was increased, their daughters in both groups decreased in mean weight at first egg.

During the last three years of the experiment there was a close correlation in body weight between mothers and daughters. In 1926 the check daughters averaged 5.68 pounds at first egg, and in 1928 their mean weight was 5.55 pounds. Inbred daughters in 1926 averaged 5.76 pounds and in 1928, 5.23 pounds. Check daughters still remained heavier than inbred daughters even after three years of inbreeding. In view of the fact that the foundation hen of all inbred lines (C 1124), weighed but 4.81 pounds at first egg, the inbred group has behaved as might be anticipated. The check group, however, has shown a slight decline in weight from inbreeding as compared with crossbreeding.

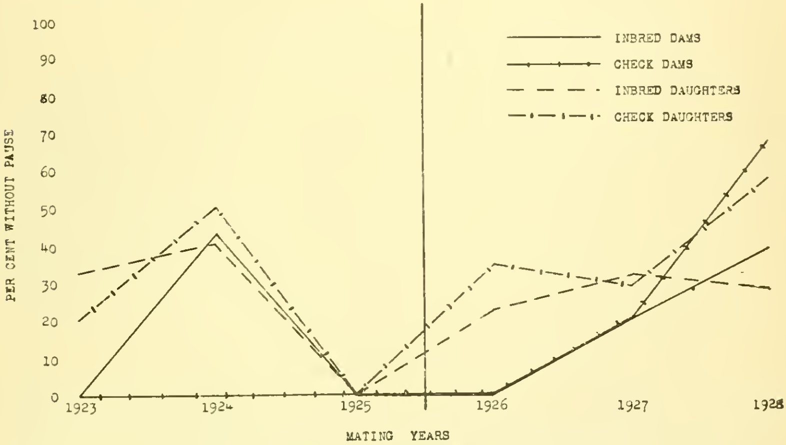

CHART 3.—Effect of Inbreeding on Winter Pause

Chart 3 presents the percentage of non-pause mothers and daughters throughout the experiment. In the beginning there were no non-pause mothers chosen for the inbred group. In 1924, 43 per cent of the inbred mothers producing daughters lacked winter pause. In 1925 all inbred mothers again showed winter pause. All check mothers with daughters up to 1925 carried winter pause.

Inbred daughters from the 1923 matings gave 33 per cent non-pause. For 1924 the percentage had risen to 40. In 1925 all inbred daughters exhibited winter pause. Check daughters of 1923 showed 20 per cent free from pause; in 1924 there was an increase to 50 per cent; and in 1925 the check daughters, like the inbred daughters, all showed winter pause. Inbreeding has not intensified winter pause because both inbred daughters and check daughters closely agree in the three years in question.

When the plan of matings was changed in 1926, all inbred mothers from which progeny were retained showed winter pause. In 1927, 20 per cent of the inbred mothers were free from pause. In 1928, 38 per cent of inbred mothers lacked winter pause. All of the check mothers of 1926 carried winter pause, 20 per cent of those used in 1927 lacked pause, and 67 per cent of those used in 1928 lacked pause. The two groups of mothers were alike with respect to winter pause up to 1928. In 1928 check mothers were far superior to inbred mothers in freedom from winter pause.

The percentage of daughters free from winter pause for the inbreds was as follows: 1926, 22 per cent; 1927, 31 per cent; and 1928, 27 per cent. For the same three-year period, check daughters exhibited 33 per cent, 27 per cent and 57 per cent free from pause. These data show that inbreeding has not affected winter pause in the inbred groups, because the inbred daughters of 1928 carried practically the same percentage of non-pause as existed in the inbred daughters of 1923. On the other hand, inbreeding the check birds for three years with selection for absence of pause in female parents has increased the percentage of non-pause birds from 20 per cent in 1923 to 57 per cent in 1928.

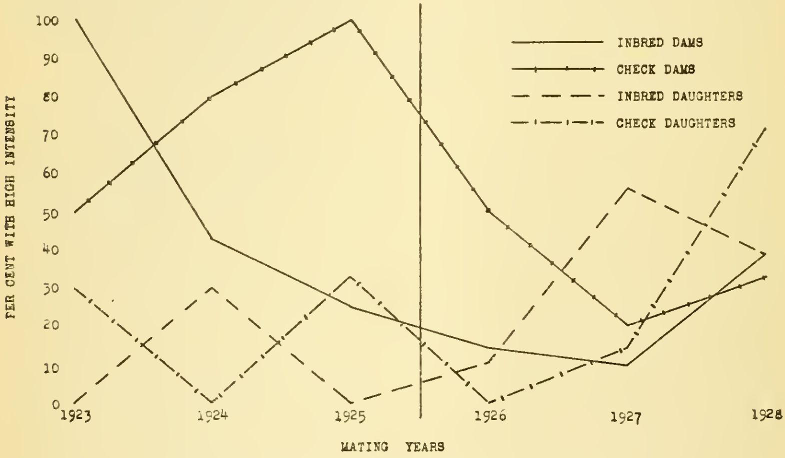

CHART 4.—Effect of Inbreeding on Intensity

Chart 4 points to a very great difference between the percentage of mothers showing genetic high intensity (clutch size 2.6 or more) and the percentage of their daughters showing high intensity. This difference was most pronounced in the inbred group during the first three years. The character of mothers used for inbreeding to produce these daughters should warrant a goodly proportion of high intensity daughters each year. Chart 4 suggests that possibly the inbred mothers laid at a slower rate because of low vigor. This observation is confirmed by the check group, when inbred during the last three years of the experiment. The check mothers used were superior to the inbred mothers in intensity during the first two years reported.

Inbred daughters were all decidedly low for intensity even in the first year of inbreeding, in the second year only 30 per cent showed high intensity, and in the third year all lacked high intensity. The check daughters of 1925 had practically the same degree of intensity as in 1923 — about 30 to 33 per cent.

When the inbred lines were crossed from 1926 to 1928, the resulting daughters showed an inprovement in intensity over previous inbred daughters. The check daughters coming from inbreeding the check lines gave no individuals with high intensity in 1926, 14 per cent high in 1927, and 71 per cent high in 1928.

These results suggest that inbreeding from a restricted foundation, as used for this inbred group, does greatly reduce intensity. On the other hand, when the foundation was less restricted, as in the check groups used, progress could be made by inbreeding with selection for high intensity.

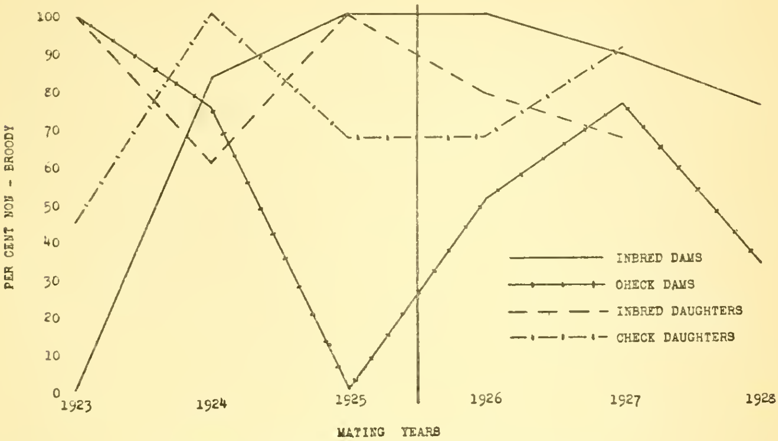

CHART 5.—Effect of Inbreeding on Broodiness

From chart 5 it will be noted that the one inbred mother in 1923 which had daughters with complete records was broody, while the mothers mated in 1924 show but 17 per cent broodiness, and the mothers in 1925 were 100 per cent free from broodiness. On the other hand, the initial group of check mothers was made up entirely of non-broody birds. The check mothers of 1924 showed 75 per cent non-broody, and the check mothers of 1926 were all broody during their pullet year.

The daughters' broody records for these three years are rather enlightening. The three inbred daughters of 1923 exhibited no broodiness during their pullet year. One of these daughters was non-broody for two years, one died early the second summer, and the third became broody during her second year. Since broodiness is a dominant trait (Hays, 1924), the mother of these daughters might be expected to transmit the broody trait to about one-fourth of her daughters, even though mated to a male lacking the broody genes. This is an illustration of the fact pointed out by Hays and Sanborn (1926) that many genetically broody birds do not exhibit the trait during the first laying year. The percentage of non-broody inbred daughters was 60 in 1924, and all were non-broody in 1925. There were but two daughters concerned in 1925, however. The check daughters of 1923 showed 45 per cent non-broody; those of 1924, 100 per cent non-broody; and those of 1925, 67 per cent non-broody. There are indications that broodiness was fast disappearing in the check birds as well as in the inbreds.

Concerning the last three years of the experiment when the plan of matings was changed, the data on the daughters are complete for only two years. The inbred mothers used were practically free from broodiness, while the check mothers were inferior to those used from 1923 to 1925. On the whole the degree of non-broodiness in the inbred daughters has changed but little in the five-year period, while broodiness has decreased for the checks.

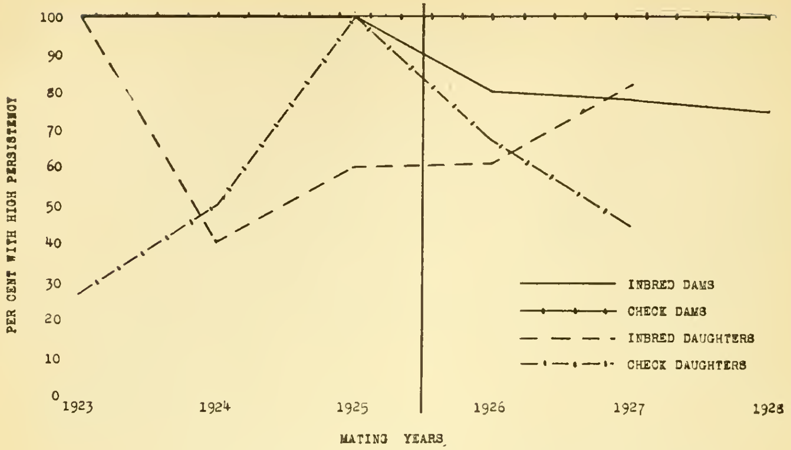

CHART 6.—Effect of Inbreeding on Persistency

Chart 6 indicates that all the check breeders which actually produced daughters showed genetic high persistency or the ability to lay for 315 days or more before molting. The inbred mothers also ran high in persistency until 1926, 1927 and 1928, when they declined to 75 and 80 per cent highly persistent.

The check daughters showed but 27 per cent high in persistency in 1923 and increased to 100 per cent in 1925. When the check groups were inbred the resulting daughters declined to 67 and 45 per cent high in persistency in 1926 and 1927. Inbred daughters were 100 per cent highly persistent the first year of the experiment. In the second year of inbreeding only 40 per cent carried high persistency, and in the third year the figure was 60 per cent high. When the inbred strains were intercrossed there was some increase in the proportion of highly persistent birds, the final figure being 82 per cent high. These data indicate that inbreeding has reduced persistency. This fact appears both in the original inbred groups and in the check groups when inbred. A rather significant point also is the fact that daughters resulting from crossing inbred strains did not exhibit as high persistency as the inbred daughters appearing in the first generation of inbreds in 1923.

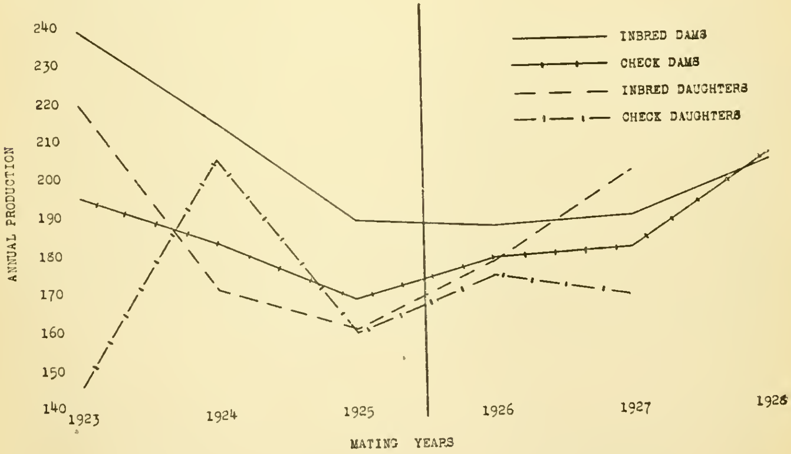

CHART 7.—Effect of Inbreeding on Annual Production

In chart 7 the inbred mothers having daughters were superior in annual egg production to the check mothers. Original inbred mothers showed a mean annual egg record of 238, compared with the original check mothers whose average was 194 eggs. The same relationship holds for the two groups up to 1928 when the mean egg record for inbred mothers was 201 and for check mothers 203.

The first group of inbred daughters hatched in 1923 showed a mean record of 219 eggs. Inbred daughters of 1924 gave a mean egg record of 170, and the inbred daughters of 1925 laid 159 eggs. Check daughters of 1923 averaged 146 eggs, those of 1924 averaged 204 eggs, while those of 1925 fell to 159 eggs. Compared with the check groups, inbreeding did not affect annual egg yield. On the basis of absolute values, however, the inbred daughters exhibited a marked and consistent decline as inbreeding progressed. On the other hand, the check daughters exhibited an upward trend in egg yield as the experiment progressed. On the whole, the data show that fecundity, as measured by annual egg yield, declined consistently in the three years of inbreeding.

For 1926 and 1927 when checks were inbred and inbred lines were crossed, the check daughters showed no significant change in annual production over the previous three years. Inbred daughters in these two years exhibited an increased production over the previous two years of inbreeding, but did not attain a production equal to that of the initial flock of inbred daughters. Intercrossing inbred lines has increased production over that of the second and third years of inbreeding, but the daughters failed to attain the level exhibited by either the foundation females or the first generation of inbred daughters.

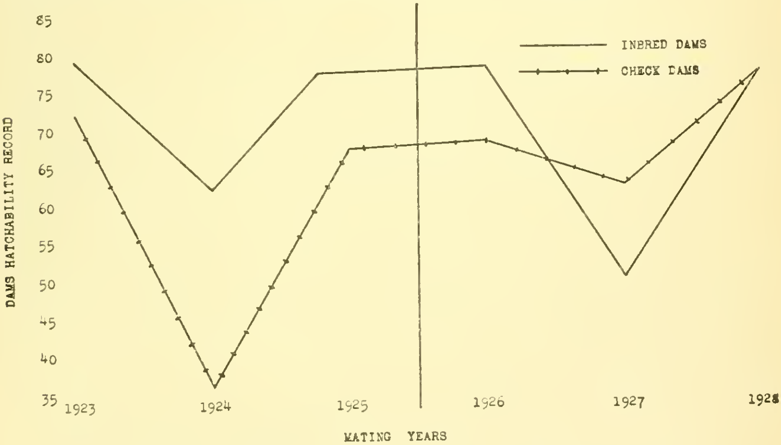

CHART 8.—Effect of Inbreeding on Hatchability (Per Cent)

Chart 8 shows the mean hatchability of dams with daughters throughout the experiment. It will be observed that the mean hatchability of the inbred dams in 1923 was 79 per cent. In 1924 the mean fell to 62 per cent, and in 1925 rose again to 77 per cent. Check mothers showed a mean hatchability of 72 per cent in 1923, 36 per cent in 1924 and 67 per cent in 1925. Inbreeding has apparently not affected hatchability the first three years.

Inbred strains when crossbred in 1926 gave the same mean hatchability, namely, 78 per cent, that was obtained during the last year of inbreeding, but the figure dropped to 50 per cent in 1927. In 1928, the mean hatchability of inbreds closely approached the original level of 79 per cent. Check females exhibited no change in hatching record in 1926 when inbred, and their hatchability slowly increased later to the same figure as shown by the inbreds, namely, 77 per cent. These data do not indicate that inbreeding has any great influence on the percentage of fertile eggs that hatch in those hens which actually produced adult daughters. This point should not be confused with previous data showing that under inbreeding more females fail to hatch any chicks.

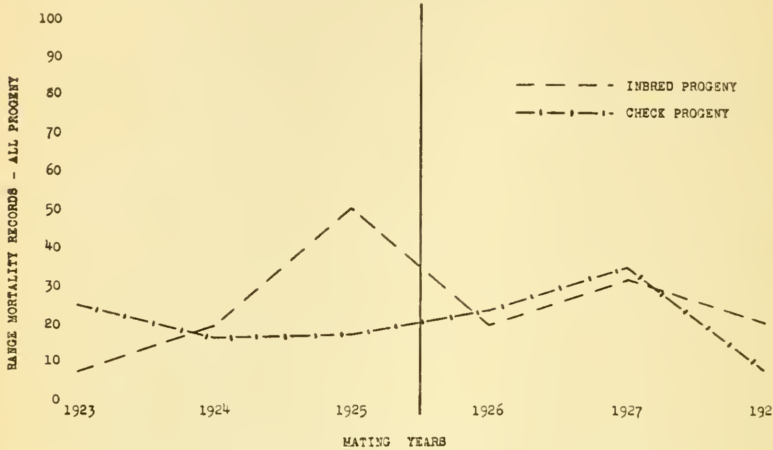

CHART 9.—Effect of Inbreeding on Chick Mortality (Per Cent Mortality to Sept. 1)

On chart 9 the mean mortality records by families for all progeny from hatching time to September first are presented. Inbred chicks showed a mortality rate of 8 per cent in 1923, 19 per cent in 1924, and 50 per cent in 1925. The chicks of the check group gave a mortality record of 25 per cent in 1923, 16 per cent in 1924, and 17 per cent in 1925. These data show that the losses in the inbred groups increased each year while the losses in the check group remained about constant. If chick mortality is a measure of vigor, inbreeding has reduced vigor.

Crossing inbred lines in 1926, 1927 and 1928 has not consistently reduced chick mortality. The mean records are 19, 31 and 20 per cent respectively. Inbreeding the check groups has not significantly affected chick mortality. The figures are as follows: 1926, 23 per cent; 1927, 34 per cent; and 1928, 8 per cent. The mortality records for the two groups rather closely approach each other. As a whole, these data signify that inbreeding did reduce chick vigor.

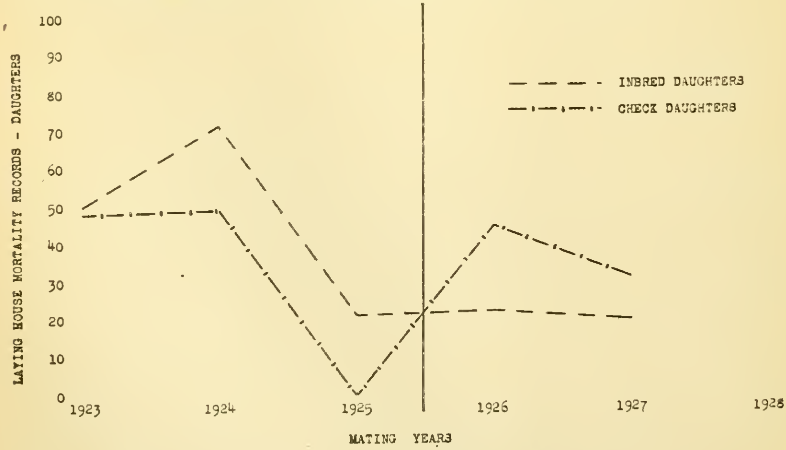

CHART 10.—Effect of Inbreeding on Laying House Mortality (Per Cent Mortality in Laying House)

The mortality records by families of daughters in the laying houses are presented graphically in chart 10. The mortality for the inbreds was 50 per cent in 1923, 71 per cent in 1924, and 21 per cent in 1925. For the check group, the figures were 48 per cent in 1923, 49 per cent in 1924, and 0 per cent in 1925. There has been a higher death rate in the inbred group for the three-year period; and in 1925, 21 per cent of the inbred daughters died while no check daughters were lost. The absolute mortality rate for the three years showed wide variability, but the close parallelism of the rates for inbreds and checks should be stressed as the only significant item to indicate lower vigor in the inbreds.

Inbred lines when crossed showed a constant laying-house mortality of 20 to 22 per cent. Check groups when inbred showed a mortality of 45 and 31 per cent for the two years recorded. Since laying-house mortality is one of the most exacting measures of vigor (Hays and Sanborn, 1928), it seems apparent that inbreeding does reduce vigor.

Summary

A study of the effects of heterosis over a two-year experimental period is reported.

The only desirable effect of heterosis observed from the standpoint of fecundity was greater body weight at a given age. The very great danger of failure from the standpoint of high fecundity when outside stock is introduced is clearly illustrated.

Inbreeding data are presented on mothers and offspring covering a six-year period. The check group was made up from a more diverse ancestry than the inbreds.

The foundation females in the inbred group consisted of one hen and her daughters. The males used were also related to these females.

During the first three years of the experiment check groups were made up of different types of outbred and straight Station-bred stock.

In the first three years the inbred groups represented different degrees of relationship, such as full brother-sister, sire on daughter, mother and son, half brother and sister.

In the last three years of the experiment, the check groups were closely inbred and the available inbred strains were intercrossed.

Inbreeding the check groups during the last three years gave results superior to those obtained with the original inbreds during the first three years. This would suggest that birds from a more diverse ancestry may be closely bred with greater safety than those from a very restricted ancestry.

The data presented do not indicate that sexual maturity was consistently and regularly retarded by inbreeding.

Body weight at first egg was not affected by inbreeding.

Winter pause, low intensity and low persistency were probably concomitants of inbreeding.

Inbreeding tended to lower production.

Inbreeding decreased fertility.

Inbreeding probably decreased hatchability.

Inbreeding tended to lower the sex ratio.

Inbreeding reduced chick vigor as well as vigor of pullets during their first laying year.

Uniformity in characteristics affecting fecundity was little affected in the inbred groups from restricted ancestry, but the check birds from more diverse ancestry became more uniform in these characteristics when inbred.

Inbred strains when intercrossed gave progeny superior to those from the second and third years of inbreeding, but not equal to the foundation stock.

In this experiment, inbreeding operated to intensify inherent weaknesses existing in the foundation stock. This trial, therefore, furnishes striking evidence of the importance of most rigorous standards in selecting stock for inbreeding purposes.

On the whole, these studies furnish no evidence of advantages that may be gained by inbreeding over the ordinary method of flock improvement by rigid selection for characteristics affecting fecundity when close matings are avoided. Since desirable fecundity traits for the most part are transmitted in Mendelian fashion, more satisfactory progress may be made by selection on the unit factor basis rather than on the individual bird basis as is necessary for inbreeding.

REFERENCES

Dunn, L. C. 1922. Hatchability and chick mortality. Poultry Sci. 1, No. 2.

Dunn, L. C. 1923. Experiments on close inbreeding in fowls. Conn. (Storrs) Agr. Expt. Sta. Bul. 111.

Dunn, L. C. 1927. The effect of inbreeding and cross-breeding on fowls. Verhand. Internat. Kong. Vererbungswissenschaft. Berlin. p. 607–617.

Goodale, H. D. 1927. Some phases of reproduction in domestic fowl. Proc. World's Poultry Congress, p. 87–92.

Hays, F. A. 1924. Inbreeding the Rhode Island Red fowl with special reference to winter egg production. Amer. Nat. 58: 43–59.

Hays, F. A. 1927. The inheritance of persistency and its relation to fecundity. Proc. World's Poultry Congress, p. 92–95.

Hays, F. A., and Ruby Sanborn. 1924. The inheritance of fertility and hatchability in poultry. Mass. Agr. Expt. Sta. Tech. Bul. 6.

Hays, F. A., and Ruby Sanborn. 1926. Broodiness in relation to fecundity in the domestic fowl. Mass. Agr. Expt. Sta. Tech. Bul. 7.

Hays, F. A., and Ruby Sanborn. 1927. Net correlations of characters concerned in fecundity. Mass. Agr. Expt. Sta. Tech. Bul. 12.

Hays, F. A., and Ruby Sanborn. 1928. Vigor in production-bred flocks. Mass. Agr. Expt. Sta. Bul. 242.

Jull, M. A. 1924. The relation of antecedent egg production to the sex ratio in the domestic fowl. Jour. Agr. Research 28: 199–224.

King, Helen D. 1918a. The effects of inbreeding on the growth and variability in the body weight of the albino rat. Jour. Expt. Zool. 26: 1–54.

King, Helen D. 1918b. The effects of inbreeding on the fertility and on the constitutional vigor of the albino rat. Jour. Expt. Zool. 26: 55–98.

King, Helen D. 1918c. The effects of inbreeding, with selection, on the sex ratio of the albino rat. Jour. Expt. Zool. 27: 1–35.

Wright, Sewall. 1922a. Coefficients of inbreeding and relationship. Amer. Nat. 56: 330–338.

Wright, Sewall. 1922b. The effects of inbreeding and cross-breeding on guinea pigs. I. Decline in vigor. II. Differentiation among inbred families. U. S. Dept. Agr. Bul. 1090.

Wright, Sewall. 1922c. The effects of inbreeding and cross-breeding on guinea pigs. III. Crosses between highly inbred families. U. S. Dept. Agr. Bul. 1121.

Publication of this Document
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3M—2—'30. No. 7834

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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 259 December, 1929

Rate of Growth in Rhode Island Reds

By F. A. Hays and Ruby Sanborn

In selecting birds for various purposes, poultrymen make extensive use of body weight as an index of the characteristics desired. The weight records presented in this report cover an eleven-year period on all living individuals in a flock bred primarily for high fecundity, and show something of their significance. The results may serve as guides to the weights which may be expected in this breed if high fecundity is the chief goal, when methods of management and climatic conditions are comparable.

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AGRICULTURAL EXPERIMENT STATION
AMHERST, MASS.

RATE OF GROWTH IN RHODE ISLAND REDS

By F. A. Hays, Research Professor of Poultry Husbandry, and
Ruby Sanborn, Research Assistant in Poultry Husbandry[1]

Introduction

Weight records are readily obtainable and probably furnish the most universal measure of results in poultry experimentation. Extensive data on rate of growth as measured by body weight are also of very great value to breeders as standards to guide their operations. In recent years, through the development of flocks with special reference to heavy egg production, there has arisen an additional use of body weights of growing chickens as a possible criterion of sexual maturity, egg size, vigor and other essentials.

In order to overcome the effects of varying environmental conditions such as temperature, humidity, amount of sunshine, or available green food, it is necessary to carry weight records over a series of years and on large numbers of individuals. Greater uniformity and consistency will be attained also if the records are made on a single strain of the breed or variety being studied.

Character of Data Available

The records used in this study cover the eleven-year period from 1918 to 1928, inclusive. The data were collected on the Massachusetts Agricultural Experiment Station flock of Rhode Island Reds, bred since 1913 with special reference to heavy egg production. This flock has been carried without introducing outside stock since 1916. Close matings have been avoided, but there is a considerable degree of relationship within the flock.

Hatching dates have remained constant throughout the period. There were eight hatches each year at weekly intervals beginning the nearest Sunday to March 25. Chicks were taken from the incubators 36 hours after hatching and placed in 10 by 12 brooder houses with coal stoves. As a rule from 200 to 250 chicks were placed in each house. All chicks were driven outside on the ground for a short period on the fourth day and were given access to outside runs with abundant grass at all times thereafter. No cod liver oil was used in feeding chicks, and a four-year range rotation with abundant grass was regularly employed. Chicks were not fasted before weighing at two weeks of age. All later weights were taken after the birds had been fasted for 12 hours.

The records presented on egg weight, chick weight at hatching and weight at two weeks were secured on stock used in hatchability studies and inbreeding studies from 1923 to 1928.

The four-week records cover the entire period from 1918 to 1928 on all Rhode Island Reds in the flock.

Records of weight at 16 weeks were obtained only in 1918 and 1921 and include all Rhode Island Reds in the flock.

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[1] Credit is also due Mr. Gordon Bearse for assistance in compiling the records.

The 21-week weight records were started in 1923 and extend through 1928. All Rhode Island Reds in the flock were weighed.

All weight records were taken individually on all living chicks.

Weights are reported in grams and also in pounds or fractions thereof. This is in agreement with the practice followed by all experiment stations in the Northeastern States.

Scope of This Report

This report furnishes a considerable body of records of weight of chicks at hatching, at 2 weeks, at 4 weeks, at 16 weeks and at 21 weeks of age.

Information is also given on the relation of egg weight to weight of chicks at hatching, at 4 weeks and at 21 weeks, to indicate possible advantages in large egg size from the standpoint of chick growth.

Extensive data on the relation of hatching date to weight of chicks at different ages are also presented.

A study is made on the relation of age of mothers to weight of chicks at 4 weeks, 16 weeks and 21 weeks of age.

The importance of early growth as a criterion of vigor and of later egg production is fully considered. Pullets that weighed under .5 pound at four weeks of age are compared for mortality rate in the laying houses and for annual egg production with those that weighed .5 pound or more. Pullets that weighed under 4.5 pounds at 21 weeks of age are compared for mortality rate in the laying houses and for annual egg production with those that weighed 4.5 pounds or over.

1. Weight of Chicks at Different Ages

Weight at Hatching

Hatching weight of these Rhode Island Red chicks varied somewhat from year to year. These variations in the six-year period covered are probably not significant. In general, the males were slightly heavier than the females. The mean hatching weight of the 640 males was 36.8 grams; of the 689 female chicks, 36.6 grams. Males were but .55 per cent heavier than females, and such a difference can not be considered significant.

Card and Kirkpatrick (1918) record the average weight of 865 Rhode Island Red chicks when hatched as 37.20 grams. Their weight records agree rather closely with those given in Table 1.

Jull and Quinn (1925) report the mean hatching weight of male Rhode Island Red chicks as 38.76 grams, and of female chicks as 37.93 grams. Their records include 228 chicks and show heavier chicks and a significantly greater difference in the weight of the sexes than do the data in Table 1.

Jull and Titus (1928) report the mean hatching weight of 83 Rhode Island Red males as 34.9 grams and of 74 females as 34.3 grams. The mean weight of their 157 chicks at hatching was 34.6 grams.

The data presented in Table 1 on the mean weight of chicks at hatching agree with those of Halbersleben and Mussehl (1922), their figure being 36.2 grams. Unfortunately their report fails to state what breed or variety of poultry was studied.

Table 1.—Normal Weight of Chicks.

Year	MALES			FEMALES			TOTAL		
	Number	Average weight Grams	(Lbs.)	Number	Average weight Grams	(Lbs.)	Number	Average weight Grams	(Lbs.)
				At Hatching					
1923	102	36.6	(.08)	132	36.5	(.08)	234	36.6	(.08)
1924	133	37.5	(.08)	123	37.1	(.08)	256	37.3	(.08)
1925	47	38.8	(.09)	57	39.0	(.09)	104	38.9	(.09)
1926	44	37.6	(.08)	37	36.3	(.08)	81	37.0	(.08)
1927	165	35.5	(.08)	186	35.4	(.08)	351	35.5	(.08)
1928	149	36.9	(.08)	154	36.9	(.08)	303	36.9	(.08)
Total	**640**	**36.8**	**(.08)**	**689**	**36.6**	**(.08)**	**1329**	**36.7**	**(.08)**
				At 2 Weeks of Age					
1923	22	114.0	(.25)	34	103.8	(.23)	56	107.8	(.24)
1924	49	98.6	(.22)	52	91.7	(.20)	101	95.0	(.21)
1925	13	80.6	(.18)	12	81.6	(.18)	25	81.1	(.18)
1926	41	90.6	(.20)	34	78.7	(.17)	75	85.2	(.19)
1927	157	83.1	(.18)	172	80.8	(.18)	329	81.9	(.18)
1928	128	90.5	(.20)	143	89.0	(.20)	271	89.7	(.20)
Total	**410**	**89.6**	**(.20)**	**447**	**86.3**	**(.19)**	**857**	**87.9**	**(.19)**
				At 4 Weeks of Age					
1918	712	230.5	(.51)	745	206.0	(.45)	1457	218.0	(.48)
1919	686	224.9	(.50)	704	204.3	(.45)	1390	214.4	(.47)
1920	300	189.9	(.42)	317	176.5	(.39)	617	183.0	(.40)
1921	729	200.1	(.44)	718	189.6	(.42)	1447	194.9	(.43)
1922	720	268.1	(.59)	712	242.1	(.53)	1432	255.2	(.56)
1923	554	259.5	(.57)	618	237.9	(.52)	1172	248.1	(.55)
1924	895	246.4	(.54)	962	234.2	(.52)	1857	240.1	(.53)
1925	626	222.7	(.49)	774	209.6	(.46)	1400	215.5	(.48)
1926	702	238.5	(.53)	774	214.7	(.47)	1476	226.0	(.50)
1927	1330	196.5	(.43)	1461	183.6	(.40)	2791	189.7	(.42)
1928	1400	198.2	(.44)	1429	189.0	(.42)	2829	193.6	(.43)
Total	**8654**	**222.4**	**(.49)**	**9214**	**206.3**	**(.45)**	**17868**	**214.1**	**(.47)**
				At 16 Weeks of Age					
1918	675	1655.1	(3.65)	720	1268.7	(2.80)	1395	1455.6	(3.21)
1921	570	1477.9	(3.26)	677	1180.6	(2.60)	1247	1316.4	(2.90)
Total	**1245**	**1574.0**	**(3.47)**	**1397**	**1226.0**	**(2.70)**	**2642**	**1390.0**	**(3.06)**
				At 21 Weeks of Age					
1923	385	2352.5	(5.19)	520	1853.8	(4.09)	905	2066.0	(4.55)
1924	360	2506.3	(5.53)	628	1915.6	(4.22)	988	2130.9	(4.70)
1925	473	2346.4	(5.17)	590	1915.5	(4.22)	1063	2107.2	(4.65)
1926	434	2429.7	(5.36)	577	1888.8	(4.16)	1011	2121.0	(4.68)
1927	360	2575.9	(5.68)	735	1981.5	(4.37)	1095	2176.9	(4.80)
1928	1093	2335.5	(5.15)	786	1866.2	(4.11)	1879	2139.2	(4.72)
Total	**3105**	**2400.1**	**(5.29)**	**3836**	**1905.7**	**(4.20)**	**6941**	**2126.9**	**(4.69)**

Upp (1928) found the average weight of 1858 Rhode Island Red chicks at hatching to be 37.70 grams. These figures agree substantially with those reported in Table 1.

From available data, the normal weight of Rhode Island Red chicks at hatching lies between 34 and 38 grams, and sex differences in weight are of little significance when the chicks are hatched.

Weight at Two Weeks of Age

Available records of weight at two weeks of age cover a six-year period from 1923 to 1928. There is no significant evidence of progressive changes in mean weight at this age observable in Table 1. The 410 males averaged 89.6 grams; the 447 females, 86.3 grams. The males therefore showed a mean weight 3.82 per cent greater than that of the females.

Card and Kirkpatrick (*loc. cit.*) found the average weight of Rhode Island Red chicks at two weeks of age to be 73.48 grams. Their records included 798 individuals.

Kaupp (*loc. cit.*) after weighing several hundred chickens gives the mean weight at two weeks for Rhode Island Reds as 72.58 grams.

Upp (*loc. cit.*) reports the mean weight of his 1858 chicks when two weeks of age as 60.69 grams.

Kaupp (*loc. cit.*) in his records found the cockerels when two weeks of age to be 5.88 per cent heavier than the pullets.

Jull and Titus (1928, *loc. cit.*) report the two-week mean weight of 83 male Rhode Island Red chicks as 79.6 grams and of 73 female chicks as 84.6 grams. The mean weight of the 156 chicks was 82.0 grams.

Available data indicate that the birds used in the studies at the Massachusetts Station were significantly heavier at two weeks than were birds studied at other stations. The normal weight of Rhode Island Red Chicks at two weeks probably ranges from 60 to 88 grams, and males run from 3 to 6 per cent heavier than females.

Weight at Four Weeks of Age

Mean weight of chicks at four weeks shows rather wide yearly fluctuations in Table 1. In the eleven-year period covered by the data there is a range from 183.0 grams in 1920 to a maximum of 255.2 grams in 1922. The very heavy weights recorded from 1922 to 1926 are probably due in part to liberal feeding of semi-solid buttermilk. During 1927 and 1928 milk was fed only in powdered form mixed in the mash.

Weight differences in the sexes appear a little more pronounced at four weeks of age. The 8654 males averaged 222.4 grams, and the 9214 females averaged 206.3 grams. Males weighed 7.80 per cent more than females at this age. Mean four-week weight of both sexes consisting of 17,868 individuals was 214.1 grams.

Card and Kirkpatrick (*loc. cit.*) give the mean four-week weight of 714 chicks as 165.11 grams.

Kaupp (*loc. cit.*) found 185.98 grams to be the average weight of a large number of Rhode Island Red chicks.

Upp (*loc. cit.*) presents records on 1581 chicks with an average four-week weight of 115.63 grams.

Jull and Titus (1928 *loc. cit*) report the mean four-week weight of 82 males as 204.5 grams. On 73 females they report a mean weight of 205.6 grams. Their 155 chicks averaged 205.0 grams.

Kaupp (*loc. cit.*) also records the males as being 12.5 per cent heavier than the females at four weeks.

These data suggest that there exists a wide variability in weight of chicks of the same strain from year to year, and also that there is a very great difference in weights obtained at four weeks by different investigators. Probably an average weight of 200 grams at four weeks would be about normal under present methods of feeding and management. Males average to weigh somewhere between 8 and 12 per cent more than females at this age.

Weight at Sixteen Weeks of Age

Data are available on the sixteen-week weight for only two years—1918 and 1921. A wide variation in mean weight in the two years is evident. A total of 1245 males averaged 1574.0 grams; the 1397 females averaged 1226.0 grams. Males were 28.38 per cent heavier than females. The total population of 2642 birds gave an average of 1390.0 grams.

Card and Kirkpatrick (*loc cit.*) present records on 288 pullets at 16 weeks. These pullets averaged 1318.6 grams.

Kaupp (*loc. cit.*) gives the average weight of both sexes at 16 weeks as 1510.5 grams. The average weight of males he gives as 1633.0 grams and of females as 1415.2 grams. His males were 15.39 per cent heavier than the females.

Jull and Titus (*loc. cit.*) report the mean weight of 77 cockerels at 16 weeks as 1852.0 grams, and of 72 pullets as 1506.6 grams. The average of the 149 birds was 1685.1 grams.

In general, the data indicate that the Rhode Island Reds studied at the Massachusetts Station were somewhat smaller at 16 weeks than those of Card and Kirkpatrick, Kaupp, and Jull and Titus. The males at Massachusetts were 28 per cent heavier than the pullets, while the males weighed by Kaupp were only 15 per cent heavier than the females.

Weight at Twenty-one Weeks of Age

Both males and females were weighed individually when 21 weeks of age for the six-year period from 1923 to 1928. Table 1 shows the number of birds weighed and the mean weight each year. Only minor fluctuations appear from year to year. It is very significant that the mean weight of both males and females in 1928 was almost the same as was recorded for 1923. A rather wide gap exists between the mean weight of males and females throughout the period. The summary shows that the 3105 males averaged 2400.1 grams, and that the 3836 females averaged 1905.7 grams. The males were 25.94 per cent heavier than the females.

Card and Kirkpatrick (*loc. cit.*) report the mean weight at 21 weeks of 251 Rhode Island Red pullets as 1746.8 grams which appears to be a rather low weight.

Kaupp (*loc. cit.*) gives the average weight at 21 weeks as 2041.2 grams. The mean weight of males in Kaupp's flock was 2272.5 grams, and the mean for females was 1846.2 grams. The males were 23.09 per cent heavier than the females.

Available data indicate that Rhode Island Red males at 21 weeks of age weigh about 2300 grams or about 5 pounds; that females weigh about 1900 grams or about 4.1 pounds; and that males average about 25 per cent heavier than females at this age. The fact that the Massachusetts strain has been bred for early sexual maturity along with heavy body weight probably accounts for the superior weight of these birds at 21 weeks. They were somewhat smaller than either those studied by Card and Kirkpatrick (*loc. cit.*) or by Kaupp (*loc. cit.*) at 16 weeks.

2. Relation of Egg Weight to Weight of Chicks

Egg size as measured by weight is of considerable economic importance due to the tendency for the market price to depend in no small degree upon the size of the eggs.

Egg size is often considered as affecting hatchability. Benjamin (1920) was unable, however, to discover a significant correlation between size and hatchability. Dunn (1922) found no relation between egg size and hatchability. Halbersleben and Mussehl (*loc. cit.*) also confirmed Dunn's findings, as was later done by Hays and Sumbardo (1927). From these and other studies it appears very unlikely that egg size does affect hatchability.

Egg size has been shown by a number of workers to be intimately correlated with the size of chicks hatched. Benjamin (*loc. cit.*) presents data to show that chick size at hatching depends upon the size of the egg, and that weight differences observed at hatching tend to persist for a considerable period of time in White Leghorns. Halbersleben and Mussehl (*loc. cit.*) show that the weight of chicks at hatching averages 64 per cent of the egg weight, but they do not mention the breed studied. Jull and Quinn (*loc. cit.*) report that Rhode Island Red chicks at hatching average 66.06 per cent of the weight of the eggs hatched. Upp (*loc. cit.*) reports that Rhode Island Red chicks average 68 per cent of the weight of the eggs hatched. Upp also notes that weight differences in chicks hatched from large and small eggs are observable at two weeks of age, but that such differences have disappeared by the age of four weeks.

Table 2.—Range in Egg Size of Female Breeders

Number of female breeders	Number of eggs weighed	Weight of eggs set	
		Grams per egg	Ounces per doz.
12	60	Under 48.6	20
21	133	48.6—50.8	21
63	363	50.9—53.2	22
101	604	53.3—55.5	23
135	821	55.6—57.9	24
130	763	58.0—60.3	25
161	901	Over 60.3	26

In Tables 2 and 3 are given data collected on the Massachusetts Station flock from 1925 to 1928. Both hens and pullets were used for breeding each year reported. The tables show the grouping of the various mothers with respect to egg size during the hatching season, together with the mean weight of their chicks at hatching, at four weeks and at 21 weeks of age.

Table 2 indicates that the dams of the chicks whose weights are reported ranged in egg size from 48.5 grams (20 oz. eggs) to 60.4 grams (26 oz. eggs). A total of 623 dams was reported on, from which 3645 hatching eggs were weighed. Only about 6 eggs from each hen were weighed at the beginning of the hatching season to obtain an index of her egg weight. Weights at two weeks of age were recorded on only a small percentage of the chicks each year, while four-week weights were taken on all chicks each year. The number of birds weighed at 21 weeks is smaller than at four weeks because of mortality and because certain undesirable families were discarded previous to the 21-week weighing.

Table 3.—Influence of Weight of Eggs on Weight of Chicks at Certain Ages.

Average weight of eggs set oz. per doz.	MALES			FEMALES			TOTAL		
	Number	Average weight Grams	(Lbs.)	Number	Average weight Grams	(Lbs.)	Number	Average weight Grams	(Lbs.)
				At Hatching					
20	0			0			0		
21	4	33.8	(.07)	5	32.4	(.07)	9	33.0	(.07)
22	8	33.6	(.07)	4	32.8	(.07)	12	33.3	(.07)
23	65	32.9	(.07)	90	32.9	(.07)	155	32.9	(.07)
24	48	34.9	(.08)	41	35.5	(.08)	89	35.2	(.08)
25	62	36.0	(.08)	75	36.4	(.08)	137	36.2	(.08)
26	181	38.8	(.09)	189	38.6	(.09)	370	38.7	(.09)
				At 4 Weeks of Age					
20	63	169.8	(.37)	68	168.7	(.37)	131	169.2	(.37)
21	126	190.0	(.42)	116	179.4	(.40)	242	184.9	(.41)
22	374	198.5	(.44)	417	180.8	(.40)	791	189.2	(.42)
23	531	198.4	(.44)	643	184.0	(.41)	1174	190.6	(.42)
24	813	203.8	(.45)	927	192.0	(.42)	1740	197.5	(.43)
25	903	209.7	(.46)	973	200.3	(.44)	1876	204.8	(.45)
26	1036	221.1	(.49)	1059	208.4	(.46)	2095	214.7	(.47)
				At 21 Weeks of Age					
20	24	2284.5	(5.04)	46	1835.8	(4.05)	70	1989.6	(4.39)
21	58	2252.2	(4.97)	60	1768.6	(3.90)	118	2006.3	(4.42)
22	174	2379.9	(5.25)	153	1923.9	(4.24)	327	2166.6	(4.78)
23	266	2334.2	(5.15)	274	1849.2	(4.08)	540	2088.1	(4.60)
24	501	2337.1	(5.15)	553	1881.8	(4.15)	1054	2098.2	(4.63)
25	570	2425.4	(5.35)	671	1935.5	(4.27)	1241	2160.5	(4.76)
26	644	2454.5	(5.41)	786	1951.0	(4.30)	1430	2177.8	(4.80)

Weight at Hatching

Hatching weight records are available on but a very small number of chicks from 21, 22 and 23 ounce eggs. The records available suggest no difference in size of chicks from these three classes. In 24, 25 and 26 ounce classes, there is observable a consistent upward trend in weight of chicks. A significant difference in hatching weight of male and female chicks does not appear in these data. The 772 chicks averaged 61.0 per cent of the weight of the eggs from their dams during the hatching season.

Weight at Four Weeks of Age

A study of the four-week weights obtained for the chicks from the different egg size groups discloses a striking correlation between egg size and four-week weight both in males and females. There is a regular and consistent increase in chick weight with an increase in egg weight. Chicks from 20-ounce eggs averaged 169.2 grams, while those from 26-ounce eggs averaged 214.7 grams—an increase of 26.9 per cent. These data fully confirm the findings of Benjamin (*loc. cit.*) with White Leghorns, but do not agree with those of Upp (*loc. cit.*) which showed that hatching weight differences in Rhode Island Reds disappear in about four weeks.

Weight at Twenty-one Weeks of Age

Reference to Table 3 indicates a much less intimate relation between the weight of either males or females at 21 weeks and the weight of eggs from which they were hatched than was observed at four weeks of age. In fact, the differences in weights of both males and females in the different egg weight classes are so slight as to be statistically insignificant. When both sexes are considered together, the birds from the 22-ounce eggs show the same mean weight as those from the 26-ounce eggs. Birds from 22 to 26 ounce eggs are about 9.1 per cent heavier than birds from 20 and 21 ounce eggs.

In general, these data indicate that weight differences in chicks at hatching are not persistent, and that such differences in Rhode Island Reds will disappear by the time the birds are about 21 weeks of age.

3. Relation of Hatching Date to Weight of Chicks

Date of hatching has a significant effect upon the weight of growing chicks as has been pointed out by Hays and Sanborn (1924) and others. The data reported in Table 4 cover available records on Rhode Island Reds from 1918 to 1928 and are the same records reported in Table 1 but regrouped according to hatching date. It will be noted that the range in hatching dates is but 49 days, since there were eight weekly hatches on corresponding dates each year. Effects of hatching date upon weight would probably be more pronounced if longer hatching seasons had been employed.

Weight at Hatching

The summary for the six-year period at the end of Table 4 does not indicate a very important relation between date of hatching and weight of chicks when hatched. There does appear to be a slight decline in the weight of the later-hatched chicks in comparison with those hatched earlier, but it is very unlikely that this small difference of slightly more than one gram is significant. The data in hand would seem to indicate, therefore, that within the limits of the 49-day range in hatching dates considered no effect on hatching weight might be expected.

Weight at Two Weeks of Age

The effects of hatching date upon chick weight begin to be noticeable at two weeks of age. The summary in Table 4 shows that the first two hatches averaged 94.85 grams, while the last two hatches averaged 83.95 grams. The chicks in the first two hatches were 12.98 per cent heavier than those in the last two hatches. There is observable a rather consistent decline in weight as the hatching date becomes later, especially after April 15. Just why the earlier chicks should attain more weight at the age of two weeks than do the later chicks is not clear.

Weight at Four Weeks of Age

The summary for Table 4 illustrates the perfect consistency of the relation between hatching date and chick weight at four weeks. The weight records include 17868 chicks so that the data are adequate for the purpose. A seven-day increase in hatching date is accompanied by a decrease in chick weight, ranging from 3.4 to 17.9 grams. For the 11-year period reported, the first hatch chicks averaged 28.79 per cent heavier than the last hatch chicks. There can be no question, therefore, that under Massachusetts conditions,

Table 4.—Relation of Hatching Date to Weight of Chicks.

		AT HATCHING		AT 2 WEEKS		AT 4 WEEKS		AT 16 WEEKS		AT 21 WEEKS	
		No.	Average weight Grams (Lbs.)	No.	Average weight Grams (Lbs.)	No.	Average weight Grams (Lbs.)	No.	Average weight Grams (Lbs.)	No.	Average weight Grams (Lbs.)
	1918										
Hatch 1	Mar. 24					189	234.6 (.52)	178	1677.4 (3.70)		
2	" 31					232	245.4 (.54)	223	1552.6 (3.42)		
3	Apr. 7					267	250.9 (.55)	257	1574.6 (3.47)		
4	" 14					214	208.3 (.46)	203	1379.9 (3.04)		
5	" 21					193	196.9 (.43)	184	1385.8 (3.06)		
6	" 28					165	199.4 (.44)	157	1310.1 (2.89)		
7	May 5					107	176.4 (.39)	104	1196.7 (2.64)		
8	" 12					90	166.3 (.37)	89	1302.9 (2.87)		
Total						1457	218.0 (.48)	1395	1455.6 (3.21)		
	1919										
Hatch 1	Mar. 23					250	229.4 (.51)				
2	" 30					171	215.5 (.48)				
3	Apr. 6					170	215.2 (.47)				
4	" 13					183	205.2 (.45)				
5	" 20					174	218.3 (.48)				
6	" 27					154	203.1 (.45)				
7	May 4					150	212.4 (.47)				
8	" 11					138	207.4 (.46)				
Total						1390	214.4 (.47)				
	1920										
Hatch 1	Mar. 28					116	178.1 (.39)				
2	Apr. 4					102	209.4 (.46)				
3	" 11					99	177.9 (.39)				
4	" 18					82	192.1 (.42)				
5	" 25					59	196.2 (.43)				
6	May 2					52	172.4 (.38)				
7	" 9					74	171.2 (.38)				
8	" 16					33	131.5 (.29)				
Total						617	183.0 (.40)				

Table 4.—Relation of Hatching Date to Weight of Chicks.—*Continued*

		AT HATCHING			AT 2 WEEKS			AT 4 WEEKS			AT 16 WEEKS			AT 21 WEEKS		
		No.	Average weight Grams	(Lbs.)	No.	Average weight Grams	(Lbs.)	No.	Average weight Grams	(Lbs.)	No.	Average weight Grams	(Lbs.)	No.	Average weight Grams	(Lbs.)
	1921															
Hatch 1	Mar. 27							388	229.3	(.51)	339	1452.0	(3.20)			
2	Apr. 3							220	222.4	(.49)	187	1349.3	(2.97)			
3	" 10							172	199.5	(.44)	133	1381.3	(3.05)			
4	" 17							180	165.6	(.37)	145	1204.2	(2.65)			
5	" 24							160	168.6	(.37)	140	1212.8	(2.67)			
6	May 1							138	174.2	(.38)	118	1267.1	(2.79)			
7	" 8							150	156.7	(.35)	148	1196.2	(2.64)			
8	" 15							39	140.5	(.31)	37	1146.3	(2.53)			
Total								**1447**	**194.9**	**(.43)**	**1247**	**1316.4**	**(2.90)**			
	1922															
Hatch 1	Mar. 26							277	285.9	(.63)						
2	Apr. 2							190	294.9	(.65)						
3	" 9							160	282.1	(.62)						
4	" 16							189	216.8	(.48)						
5	" 23							146	210.0	(.46)						
6	" 30							208	252.1	(.56)						
7	May 7							127	243.7	(.54)						
8	" 14							135	222.7	(.49)						
Total								**1432**	**255.2**	**(.56)**						
	1923															
Hatch 1	Mar. 25	20	37.50	(.083)	1	99.8	(.22)	107	323.1	(.71)				84	2201.3	(4.85)
2	Apr. 1	19	36.68	(.081)				106	297.8	(.66)				84	2195.2	(4.84)
3	" 8	21	37.48	(.083)	3	117.9	(.26)	130	279.8	(.62)				94	2188.4	(4.82)
4	" 15	36	36.75	(.081)	6	98.3	(.22)	153	253.9	(.56)				125	2056.4	(4.53)
5	" 22	30	37.10	(.082)	11	126.2	(.28)	141	258.9	(.57)				116	2179.5	(4.81)
6	" 29	34	36.06	(.080)	12	100.2	(.22)	165	223.5	(.49)				136	2025.4	(4.47)
7	May 6	41	36.17	(.080)	11	113.4	(.25)	181	212.6	(.47)				142	1878.2	(4.14)
8	" 13	33	35.79	(.079)	12	96.4	(.21)	189	199.0	(.44)				124	1956.8	(4.31)
Total		**234**	**36.58**	**(.081)**	**56**	**107.8**	**(.24)**	**1172**	**248.1**	**(.55)**				**905**	**2066.0**	**(4.55)**

Table 4.—Relation of Hatching Date to Weight of Chicks.—*Continued*

			AT HATCHING			AT 2 WEEKS			AT 4 WEEKS			AT 16 WEEKS			AT 21 WEEKS		
			No.	Average weight Grams	(Lbs.)	No.	Average weight Grams	(Lbs.)	No.	Average weight Grams	(Lbs.)	No.	Average weight Grams	(Lbs.)	No.	Average weight Grams	(Lbs.)
		1924															
Hatch	1	Mar. 23	36	39.14	(.086)	8	110.6	(.24)	222	269.9	(.60)				120	2190.1	(4.83)
	2	" 30	22	36.82	(.081)	13	107.1	(.24)	151	262.2	(.58)				88	2134.9	(4.71)
	3	Apr. 6	45	36.64	(.081)	22	100.8	(.22)	209	258.0	(.57)				132	2216.8	(4.89)
	4	" 13	44	38.05	(.084)	18	88.2	(.19)	273	240.6	(.53)				143	2133.4	(4.70)
	5	" 20	24	37.29	(.082)	7	82.3	(.18)	242	231.9	(.51)				135	2202.7	(4.86)
	6	" 27	24	36.54	(.081)	10	86.6	(.19)	241	225.7	(.50)				122	2114.4	(4.66)
	7	May 4	25	36.96	(.081)	13	95.6	(.21)	246	233.0	(.51)				117	2057.2	(4.54)
	8	" 11	36	36.47	(.080)	10	83.0	(.18)	273	215.8	(.48)				131	1991.4	(4.39)
Total			**256**	**37.31**	**(.082)**	**101**	**95.0**	**(.21)**	**1857**	**240.1**	**(.53)**				**988**	**2130.9**	**(4.70)**
		1925															
Hatch	1	Mar. 29	11	38.82	(.086)	2	86.2	(.19)	275	257.9	(.57)				214	2273.3	(5.01)
	2	Apr. 5	17	40.12	(.088)	3	102.8	(.23)	212	255.1	(.56)				177	2200.6	(4.85)
	3	" 12	11	39.45	(.087)	3	87.7	(.19)	173	235.4	(.52)				108	2184.9	(4.82)
	4	" 19	13	39.31	(.087)				146	206.3	(.45)				113	2013.4	(4.44)
	5	" 26	19	38.84	(.086)	7	73.2	(.16)	185	191.2	(.42)				133	2020.9	(4.46)
	6	May 3	10	38.50	(.085)	3	84.7	(.19)	134	179.0	(.39)				108	2066.5	(4.56)
	7	" 10	13	37.92	(.084)	3	71.1	(.16)	149	159.5	(.35)				115	1972.6	(4.35)
	8	" 17	10	37.60	(.083)	4	76.0	(.17)	126	179.9	(.40)				95	1912.7	(4.22)
Total			**104**	**38.90**	**(.086)**	**25**	**81.1**	**(.18)**	**1400**	**215.5**	**(.48)**				**1063**	**2107.2**	**(4.65)**
		1926															
Hatch	1	Mar. 28	3	39.33	(.087)	4	99.8	(.22)	86	282.9	(.62)				60	2220.6	(4.90)
	2	Apr. 4	2	40.00	(.088)	2	108.9	(.24)	87	269.8	(.59)				52	2190.5	(4.83)
	3	" 11	2	41.50	(.092)	3	87.7	(.19)	56	230.4	(.51)				32	2047.9	(4.51)
	4	" 18	8	39.13	(.086)	6	105.1	(.23)	174	239.2	(.53)				105	2122.8	(4.68)
	5	" 25	18	36.22	(.080)	16	84.8	(.19)	340	220.5	(.49)				218	2173.5	(4.79)
	6	May 2	23	36.65	(.081)	21	73.7	(.16)	287	230.1	(.51)				202	2181.5	(4.81)
	7	" 9	14	37.43	(.083)	13	89.3	(.20)	243	217.6	(.48)				187	2095.5	(4.62)
	8	" 16	11	35.00	(.077)	10	81.6	(.18)	203	183.9	(.41)				155	1951.2	(4.30)
Total			**81**	**37.01**	**(.082)**	**75**	**85.2**	**(.19)**	**1476**	**226.0**	**(.50)**				**1011**	**2121.0**	**(4.68)**

Table 4.—Relation of Hatching Date to Weight of Chicks.—*Continued*

		AT HATCHING			AT 2 WEEKS			AT 4 WEEKS			AT 16 WEEKS			AT 21 WEEKS		
		No.	Average weight Grams	(Lbs.)	No.	Average weight Grams	(Lbs.)	No.	Average weight Grams	(Lbs.)	No.	Average weight Grams	(Lbs.)	No.	Average weight Grams	(Lbs.)
	1927															
Hatch 1	Mar. 27	36	36.92	(.081)	34	88.9	(.20)	437	214.7	(.47)				241	2349.3	(5.18)
2	Apr. 3	29	36.41	(.080)	28	95.1	(.21)	344	217.1	(.48)				184	2319.5	(5.11)
3	" 10	28	37.71	(.083)	27	80.5	(.18)	345	203.8	(.45)				157	2254.9	(4.97)
4	" 17	66	35.24	(.078)	64	86.3	(.19)	427	195.4	(.43)				196	2219.5	(4.89)
5	" 24	38	35.34	(.078)	34	75.5	(.17)	309	169.2	(.37)				89	1890.7	(4.17)
6	May 1	55	35.47	(.078)	52	75.8	(.17)	374	169.0	(.37)				110	1895.9	(4.18)
7	" 8	72	33.69	(.074)	64	77.0	(.17)	359	168.2	(.37)				107	1895.8	(4.18)
8	" 15	27	35.41	(.078)	26	82.5	(.18)	196	160.3	(.35)				11	2005.3	(4.42)
Total		351	35.45	(.078)	329	81.9	(.18)	2791	189.7	(.42)				1095	2176.9	(4.80)
	1928															
Hatch 1	Mar. 25	46	37.83	(.083)	35	97.5	(.21)	406	214.4	(.47)				283	2251.5	(4.96)
2	Apr. 1	40	37.40	(.082)	33	87.6	(.19)	373	200.2	(.44)				266	2311.3	(5.10)
3	" 8	40	36.53	(.081)	37	106.0	(.23)	416	204.9	(.45)				262	2210.7	(4.87)
4	" 15	46	36.50	(.080)	43	95.3	(.21)	432	199.0	(.44)				282	2051.0	(4.52)
5	" 22	29	37.31	(.082)	27	77.3	(.17)	374	193.3	(.43)				260	2162.0	(4.77)
6	" 29	38	37.08	(.082)	37	85.7	(.19)	325	195.3	(.43)				221	2146.2	(4.73)
7	May 6	33	35.48	(.078)	32	71.0	(.16)	250	151.5	(.33)				153	1900.6	(4.19)
8	" 13	31	36.81	(.081)	27	90.9	(.20)	253	161.9	(.36)				152	1860.5	(4.10)
Total		303	36.89	(.081)	271	89.7	(.20)	2829	193.6	(.43)				1879	2139.2	(4.72)
SUMMARY																
Hatch 1		152	37.98	(.084)	84	95.1	(.21)	2753	240.2	(.53)	517	1529.6	(3.37)	1002	2266.3	(5.00)
2		129	37.37	(.082)	79	94.6	(.21)	2188	236.8	(.52)	410	1459.9	(3.22)	851	2253.0	(4,97)
3		147	37.21	(.082)	95	96.8	(.21)	2197	227.6	(.50)	390	1508.7	(3.33)	785	2207.7	(4.87)
4		213	36.74	(.081)	137	90.7	(.20)	2453	209.7	(.46)	348	1306.7	(2.88)	964	2101.6	(4.63)
5		158	36.85	(.081)	102	83.2	(.18)	2323	203.5	(.45)	324	1311.0	(2.89)	951	2127.4	(4.69)
6		184	36.36	(.080)	135	81.3	(.18)	2243	204.0	(.45)	275	1291.6	(2.85)	899	2091.4	(4.61)
7		198	35.46	(.078)	136	81.3	(.18)	2036	190.9	(.42)	252	1196.4	(2.64)	821	1972.9	(4.35)
8		148	36.16	(.080)	89	86.6	(.19)	1675	186.5	(.41)	126	1256.9	(2.77)	668	1934.9	(4.27)
Grand Total		1329	36.70	(.081)	857	87.9	(.19)	17868	214.1	(.47)	2642	1390.0	(3.06)	6941	2126.9	(4.69)

late March hatching is superior to later hatching from the standpoint of chick weight at four weeks of age.

Weight at Sixteen Weeks of Age

Records of 16-week weights of chicks are available only for 1918 and 1921. The total number of chicks weighed was 2642. Although this number is rather small, it nevertheless furnishes some criterion of the relation of hatching date to chick weight at this age. The summary at the end of Table 4 discloses a fairly consistent decline in 16-week mean weights with weekly advances of the hatching date. The first hatch chicks averaged 21.70 per cent heavier than the last hatch chicks at the same age. This difference is somewhat less pronounced than was observed at four weeks when the first hatch chicks weighed 28.79 per cent more than the last hatch chicks.

Weight at Twenty-one Weeks of Age

Data on weight at 21 weeks cover the six-year period from 1923 to 1928. The total number of birds included is 6941. The summary indicates something of a downward trend in mean weight as the hatching date advances. The 1002 birds in the first hatch averaged 17.13 per cent heavier than the 668 birds in the last hatch. A more rapid growth rate enables the early hatched pullets to attain more weight when sexually mature because hatching date within these limits does not affect age at sexual maturity (Hays, Sanborn and James 1924, *loc. cit.*). On the whole, for Rhode Island Reds under Massachusetts conditions, late March hatching is superior to later hatching from the standpoint of body weight to at least 21 weeks of age.

4. Relation of Age of Mothers to Weight of Chicks

The writer (Hays, 1929) has shown that in the Massachusetts Agricultural Experiment Station flock of Rhode Island Reds the mean weight of eggs during the hatching season from 84 birds was as follows: pullets, 55.90 grams; yearlings, 60.12 grams, with no further increase in egg weight after the yearling season. Since there is an intimate correlation between egg weight and chick weight at hatching, it seems logical to anticipate that chicks from hen mothers would be superior in weight at hatching and might retain this greater weight for a period after hatching. Table 6 gives the record of chick weights at hatching, at 4 weeks, at 16 weeks and at 21 weeks of age from hen mothers and from pullet mothers.

Weight of Eggs

The mean egg weight during the hatching season for all of the females whose offspring was weighed is recorded in Table 5. The mean weight of eggs for the pullet mothers was 56.19 grams and for the hens was 59.56 grams. These data agree well with previous data already referred to from this Station on the mean weight of pullet eggs and yearling eggs during the hatching season (Hays, 1929, *loc. cit.*). Egg weights recorded in Table 5 are also in complete agreement with those reported by Jull and Quinn (*loc. cit.*).

Table 5.—Relation of Age of Mothers to Egg Weight.

	MEAN WEIGHT OF HATCHING EGGS—GRAMS	
Year	Pullet mothers	Hen mothers
1925	56.39	60.97
1926	55.92	60.67
1927	55.42	58.91
1928	56.86	58.48
Average	**56.19**	**59.56**

Weight of Chicks at Hatching

The 743 chicks from pullet mothers had a mean weight of 35.9 grams, and the 586 from hen mothers averaged 37.7 grams. The chicks from hen mothers were 5.01 per cent heavier than those from pullet mothers. Jull and Quinn (*loc. cit.*) report about the same relative difference in hatching weight of both male and female chicks from pullet mothers versus hen mothers but their chicks were slightly heavier than those reported in Table 6.

Weight of Chicks at Four Weeks of Age

At the age of four weeks both male and female chicks from hen mothers were heavier than those from pullet mothers. The 8759 chicks from hen mothers averaged 17.7 grams or 8.62 per cent heavier than the 9109 chicks from pullet mothers. The fact should be noted in this connection that the hen eggs incubated averaged 6.00 per cent heavier than the pullet eggs, and the chicks from hen mothers were 5.01 per cent heavier at hatching than those from pullet mothers. These data therefore indicate that the relative weight difference in chicks from pullet mothers and hen mothers persisted at four weeks of age.

Weight of Chicks at Sixteen Weeks of Age

At the age of 16 weeks there was still a significant weight difference in both male and female chicks from pullet mothers and from hen mothers. The mean 16-week weight for 2003 chicks from pullet mothers was 1366.9 grams, and for 639 chicks from hen mothers the weight was 1462.2 grams. The chicks from hen mothers were 6.97 per cent heavier, indicating a significant difference in weight at 16 weeks between chicks from pullets and from hens.

Weight of Chicks at Twenty-one Weeks of Age

Table 6 presents data to indicate that when chicks from pullet mothers were compared with those from hen mothers at 21 weeks of age, weight differences observed earlier had practically disappeared. The 1259 males from pullet dams averaged 2366.9 grams compared with 1846 males from hen mothers with an average weight of 2422.8 grams. Since the actual difference was small, and because there was lack of consistency from year to year as shown in the table, it is very probable that the difference is not significant. For the female chicks, the mean weights from the two classes of mothers were almost identical at 21 weeks. When the sexes were taken together, pullet offspring had practically the same mean weight as hen offspring.

In general, the data in Table 5 and 6 show that hen mothers laid larger

Table 6.—Relation of Age of Mothers to Weight of Chicks.

Year	Mothers	MALES			FEMALES			TOTAL		
		Number	Average weight Grams	(Lbs.)	Number	Average weight Grams	(Lbs.)	Number	Average weight Grams	(Lbs.)
At Hatching										
1923	Pullet	96	36.6	(.08)	126	36.6	(.08)	222	36.6	(.08)
	Hen	6	36.3	(.08)	6	36.2	(.08)	12	36.3	(.08)
1924	Pullet	24	35.8	(.08)	23	33.0	(.07)	47	34.4	(.08)
	Hen	109	37.9	(.08)	100	38.0	(.08)	209	38.0	(.08)
1925	Pullet	10	38.3	(.08)	9	37.9	(.08)	19	38.1	(.08)
	Hen	37	38.9	(.09)	48	39.2	(.09)	85	39.1	(.09)
1926	Pullet	31	37.2	(.08)	33	35.9	(.08)	64	36.5	(.08)
	Hen	13	38.5	(.08)	4	40.3	(.09)	17	38.9	(.09)
1927	Pullet	113	34.8	(.08)	126	34.9	(.08)	239	34.8	(.08)
	Hen	52	37.1	(.08)	60	36.5	(.08)	112	36.8	(.08)
1928	Pullet	76	36.8	(.08)	76	36.5	(.08)	152	36.6	(.08)
	Hen	73	37.0	(.08)	78	37.3	(.08)	151	37.2	(.08)
Total	**Pullet**	**350**	**36.1**	**(.08)**	**393**	**35.8**	**(.08)**	**743**	**35.9**	**(.08)**
	Hen	**290**	**37.7**	**(.08)**	**296**	**37.7**	**(.08)**	**586**	**37.7**	**(.08)**
At 4 Weeks of Age										
1918	Pullet	454	225.6	(.50)	474	202.0	(.45)	928	213.5	(.47)
	Hen	258	239.1	(.53)	271	213.0	(.47)	529	225.7	(.50)
1919	Pullet	364	220.0	(.49)	385	202.0	(.45)	749	210.7	(.46)
	Hen	322	230.4	(.51)	319	207.0	(.46)	641	218.8	(.48)
1920	Pullet	149	178.8	(.39)	161	169.3	(.37)	310	173.9	(.38)
	Hen	151	200.9	(.44)	156	184.1	(.41)	307	192.3	(.42)
1921	Pullet	663	199.2	(.44)	654	188.5	(.42)	1317	193.9	(.43)
	Hen	66	209.5	(.46)	64	201.1	(.44)	130	205.4	(.45)
1922	Pullet	354	253.4	(.56)	392	231.6	(.51)	746	241.9	(.53)
	Hen	366	282.4	(.62)	320	255.1	(.56)	686	269.6	(.59)
1923	Pullet	234	255.1	(.56)	265	237.6	(.52)	499	245.9	(.54)
	Hen	320	262.8	(.58)	353	238.1	(.53)	673	249.8	(.55)
1924	Pullet	310	227.8	(.50)	356	224.8	(.50)	666	226.2	(.50)
	Hen	585	256.3	(.57)	606	239.7	(.53)	1191	247.8	(.55)
1925	Pullet	217	209.9	(.46)	282	196.1	(.43)	499	202.1	(.45)
	Hen	409	229.5	(.51)	492	217.4	(.48)	901	222.9	(.49)
1926	Pullet	352	228.8	(.50)	378	203.3	(.45)	730	215.6	(.48)
	Hen	350	248.2	(.55)	396	225.5	(.50)	746	236.2	(.52)
1927	Pullet	465	180.4	(.40)	589	171.6	(.38)	1054	175.5	(.39)
	Hen	865	205.1	(.45)	872	191.7	(.42)	1737	198.4	(.44)
1928	Pullet	824	197.2	(.43)	787	186.1	(.41)	1611	191.8	(.42)
	Hen	576	199.6	(.44)	642	192.6	(.42)	1218	195.9	(.43)
Total	**Pullet**	**4386**	**212.9**	**(.47)**	**4723**	**198.5**	**(.44)**	**9109**	**205.4**	**(.45)**
	Hen	**4268**	**232.1**	**(.51)**	**4491**	**214.5**	**(.47)**	**8759**	**223.1**	**(.49)**
At 16 Weeks of Age										
1918	Pullet	427	1617.3	(3.57)	458	1249.3	(2.75)	885	1426.8	(3.15)
	Hen	248	1720.3	(3.79)	262	1302.7	(2.87)	510	1505.8	(3.32)
1921	Pullet	505	1482.3	(3.27)	613	1185.4	(2.61)	1118	1319.5	(2.91)
	Hen	65	1443.7	(3.18)	64	1134.0	(2.50)	129	1290.0	(2.84)
Total	**Pullet**	**932**	**1544.1**	**(3.40)**	**1071**	**1212.7**	**(2.67)**	**2003**	**1366.9**	**(3.01)**
	Hen	**313**	**1662.9**	**(3.67)**	**326**	**1269.6**	**(2.80)**	**639**	**1462.2**	**(3.22)**
At 21 Weeks of Age										
1923	Pullet	158	2371.3	(5.23)	223	1864.1	(4.11)	381	2074.4	(4.57)
	Hen	227	2339.5	(5.16)	297	1846.0	(4.07)	524	2059.8	(4.54)
1924	Pullet	95	2453.3	(5.41)	178	1874.3	(4.13)	273	2075.8	(4.58)
	Hen	265	2525.3	(5.57)	450	1932.0	(4.26)	715	2151.9	(4.74)
1925	Pullet	130	2319.2	(5.11)	172	1899.0	(4.19)	302	2079.9	(4.59)
	Hen	343	2356.7	(5.20)	418	1922.3	(4.24)	761	2118.1	(4.67)
1926	Pullet	174	2459.5	(5.42)	260	1885.7	(4.16)	434	2115.8	(4.66)
	Hen	260	2409.8	(5.31)	317	1891.3	(4.17)	577	2124.9	(4.68)
1927	Pullet	87	2481.3	(5.47)	181	1962.7	(4.33)	268	2131.1	(4.70)
	Hen	273	2606.0	(5.75)	554	1987.7	(4.38)	827	2191.8	(4.83)
1928	Pullet	615	2320.2	(5.12)	357	1852.7	(4.08)	972	2148.5	(4.74)
	Hen	478	2355.4	(5.19)	429	1877.4	(4.14)	907	2129.3	(4.69)
Total	**Pullet**	**1259**	**2366.9**	**(5.22)**	**1371**	**1884.0**	**(4.15)**	**2630**	**2115.2**	**(4.66)**
	Hen	**1846**	**2422.8**	**(5.34)**	**2465**	**1917.8**	**(4.23)**	**4311**	**2134.0**	**(4.70)**

eggs than pullet mothers. These eggs hatched into larger chicks which retained their weight advantage to about 16 weeks of age. At 21 weeks of age, chicks from pullet mothers approached the same mean weight as chicks from hen mothers. In the light of these data and other data presented by Hays (1928), chicks from hen mothers appeared to be superior to those from pullet mothers only up to about four months of age.

5. Relation of Early Growth to Future Vigor and Egg Production

Table 7 presents data on the relation of body weight of pullets at four weeks of age and at 21 weeks of age to vigor and to their later egg production. Vigor in this case is measured by the mortality rate in the laying houses during the first laying year for all pullets housed. This measure of vigor was suggested by Hays and Sanborn (1928) in previous studies on the same flock. Pullets were classed as *small* if they weighed less than .5 lb. at four weeks of age and as *large* if they weighed .5 lb or over. At the age of 21 weeks the *small* group was made up of birds weighing less than 4.5 lbs. and the *large* group of birds weighing 4.5 lbs. or more. Such a grouping is purely arbitrary but furnishes a working basis in selecting pullets to be retained for egg production purposes.

Vigor

Table 7 shows that the *small* pullets at four weeks of age exhibited a higher mortality rate in the laying houses than the *large* pullets in each of the five years reported. This consistent difference suggests superior vigor in the large birds. However, when the weighted mean mortality rate is considered for the entire period, there is a difference of but 1.41 per cent in favor of the *large* group. On the whole, these data, while not conclusive, suggest the probability that rapid growth up to four weeks of age is associated with superior vigor to some extent.

Table 7.—Relation of Weight of Pullets to Mortality Rate in Laying Houses and to Annual Egg Production.

At 4 Weeks of Age

	SMALL—UNDER .5 POUND				LARGE—.5 POUND OR OVER			
Year	Number in laying houses	Mortality in laying houses		Annual egg production	Number in laying houses	Mortality in laying houses		Annual egg product-tion
		Number	*Per cent*			Number	*Per cent*	
1923	168	50	*29.76*	183.7	333	83	*24.92*	189.5
1924	193	110	*56.99*	187.5	364	179	*49.18*	191.2
1925	346	94	*27.17*	199.6	264	52	*19.70*	202.8
1926	312	109	*34.94*	197.5	256	69	*26.95*	200.5
1927	586	147	*25.09*	195.9	153	33	*21.57*	193.8
Total	1605	510	31.78	195.3	1370	416	30.37	195.6

At 21 Weeks of Age

	SMALL—UNDER 4.5 POUNDS				LARGE—4.5 POUNDS OR OVER			
1923	377	100	*26.53*	190.1	121	26	*21.49*	185.2
1924	388	199	*51.29*	190.6	167	87	*52.10*	188.7
1925	389	97	*24.94*	198.4	186	38	*20.43*	203.9
1926	390	121	*31.03*	198.3	178	58	*32.58*	199.4
1927	429	103	*24.01*	197.8	303	74	*24.42*	192.4
Total	1973	620	31.43	195.5	955	283	29.63	194.9

Further reference to Table 7 brings to light the fact that body weight of pullets at 21 weeks of age is not an index of vigor. The table clearly shows that the mortality rate for pullets weighing 4.5 pounds or over at 21 weeks was substantially the same as for pullets weighing under 4.5 pounds at the same age. The table also indicates that 4.5 pounds is a rather high standard of weight for pullets of the flock studied, because less than one-third (31 per cent) of the birds actually fell into the *large* class. These data are in agreement with previous data reported by Hays and Sanborn (1928 *loc. cit.*) to the effect that weight at first egg (about 180 days) is independent of mortality rate in the laying houses.

From the standpoint of vigor, the data in Table 7 indicate: First, that heavy weight at 4 weeks of age does indicate superior vigor in pullets; and second, that heavy weight at 21 weeks of age is not a criterion of vigor.

Egg Production

A study of the mean annual egg records of pullets in the *large* and *small* weight classes at 4 weeks of age suggests a slight superiority in the *large* class in the first four years reported. However, when the mean annual production of the 1605 birds classed as *small* is compared with the same figure for the 1370 birds classed as *large* at the end of the table, all differences disappear. The actual average annual egg records are 195.3 and 195.6 respectively.

Pullets weighing less than 4.5 pounds at 21 weeks of age exhibit no significant difference in their first-year egg records from pullets weighing 4.5 pounds or more at 21 weeks. The mean egg record of 1973 birds in the first class is 195.5 eggs: and for the 955 birds in the second class, 194.9 eggs. On the basis of these data, neither four-week weights nor 21-week weights furnish any criterion of future egg yield.

Summary

1. The normal weights of Rhode Island Red chicks in the Massachusetts Agricultural Experiment Station flock are 36.7 grams (.08 lb.) at hatching; 87.9 grams (.19 lb.) at 2 weeks; 214.1 grams (.47 lb) at 4 weeks; 1390.0 grams (3.06 lbs.) at 16 weeks; and 2126.9 grams (4.69 lbs.) at 21 weeks.

2. The dams of a part of the chicks used in these studies are grouped in classes with respect to their egg weight during the hatching season. Chick weight at hatching varied from 33 grams for the small egg dams, up to 38.7 grams for the large egg dams. The weight differences in these chicks persisted at 4 weeks of age, when the chicks from the large eggs were 26.9 per cent heavier than the chicks from the small eggs in the extreme classes. At the age of 21 weeks, weight differences in chicks hatched from large and small eggs had disappeared.

3. Hatching date ranging over a 49-day period affected the weight of chicks throughout most of the growing season. The difference in mean hatching weight of the chicks in the first and last hatches was not striking, but the early hatched chicks were 12.98 per cent heavier than the late hatched chicks at 2 weeks of age, 28.79 per cent heavier at 4 weeks of age, 21.70 per cent heavier at 16 weeks of age, and 17.12 per cent heavier at 21 weeks of age.

4. The weights of chicks from pullet mothers were compared with those from hen mothers. At hatching, the chicks from hen mothers were 5.01 per cent heavier than those from pullet mothers. At 4 weeks of age the chicks from hens were 8.62 per cent heavier. At 16 weeks of age the chicks from hens were 6.97 per cent heavier than those from pullets. When the chicks reached the age of 21 weeks there appeared to be no significant difference in weights between those from hen mothers and those from pullet mothers.

5. The chicks used in these studies averaged 61.00 per cent of the weight of the eggs from which they were hatched.

6. The mean weight of hatching eggs from pullet mothers was 56.19 grams and from hen mothers 59.56 grams.

7. Pullets weighing less than .5 pound at 4 weeks of age were slightly less vigorous than those attaining .5 pound or more at that age.

8. No difference in vigor was observed, however, in pullets weighing less than 4.5 pounds at 21 weeks of age and those weighing 4.5 pounds or more at that age.

9. Heavy weight at 4 weeks of age or at 21 weeks of age was no criterion of pullet-year egg production.

References

Benjamin, E. W. 1920. A study of selections for the size, shape and color of hens' eggs. N. Y. (Cornell) Agr. Expt. Sta. Memoir 31.

Card, L. E. and W. F. Kirkpatrick. 1918. Rearing chickens. Conn. (Storrs) Agri. Expt. Sta. Bul. 96.

Dunn, L. C. 1922. The relationship between the weight and the hatching quality of eggs. Conn. (Storrs) Agr. Expt. Sta. Bul. 109.

Halbersleben, D. L. and F. E. Mussehl. 1922. Relationship of egg weight to chick weight at hatching. Poultry Sci. 1:143-144.

Hays, F. A., Ruby Sanborn and L. L. James. 1924. Correlation studies on winter fecundity. Mass. Agr. Expt. Sta. Bul. 220.

Hays, F. A. and A. H. Sumbardo. 1927. Physical character of eggs in relation to hatchability. Poultry Sci. 6:196-200.

Hays, F. A. 1928. Relation of age of parents to hatchability, livability and fecundity in the domestic fowl. Poultry Sci. 7:106-115.

Hays, F. A. and Ruby Sanborn. 1928. Vigor in production-bred flocks. Mass. Agr. Expt. Sta. Bul. 242.

Hays, F. A. 1929. The inheritance of egg weight in the domestic fowl. Jour. Agr. Research 38:511-519.

Jull, M. A. and J. P. Quinn. 1925. The relationship between the weight of eggs and the weight of chicks according to sex. Jour. Agr. Research 31:223-226.

Jull, M. A. and H. W. Titus. 1928. Growth of chicks in relation to feed consumption. Jour. Agr. Research 36:541-550.

Kaupp, B. F. 1921. The rate of growth of single comb Rhode Island Reds. Poultry Sci. 1:39-43.

Upp, C. W. 1928. Egg weight, day old chick weight, and rate of growth in single comb Rhode Island Red chicks. Poultry Sci. 7:151-155.

Publication of this document approved by the
Commission on Administration and Finance
3 m-2-'30. No. 8044

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 260 MARCH, 1930

Annual Report

For the Fiscal Year Ending Nov. 30, 1929

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

Requests for Bulletins should be addressed to the

AGRICULTURAL EXPERIMENT STATION,
AMHERST, MASS.

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

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Frost, Harold L., Arlington	1931
Richardson, Carlton, D., West Brookfield	1932
Russell, Howard S., Waltham	1936
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ANNUAL REPORT OF THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION—1929

INTRODUCTION

F. J. Sievers, Director

With the rapid industrial changes and developments which have been especially evident during the last half century throughout many portions of the world, and particularly in this country, an increasing portion of the consuming public has become farther removed from its direct dependency upon products of the farm. Prior to this period of marked industrial progress, or evolution, the difficulty of wresting the products of agriculture from the soil and of preparing them for use was so pronounced that it required practically all of the labor of our entire employed population. The farm and the home furnished the main market for the employment of labor: and the demands of the average consumer, beyond the bare necessities of life, were comparatively few. This applied especially to those demands that involved cash expenditures. The expenses and cash outlays for most farm practices were not considered sufficiently significant to make it necessary to keep farm accounts or to determine with any degree of accuracy just what the costs of farm management operations were. That the economics of farm and home management did not require the same consideration as today is evidenced by the fact that many farms and farm homes were maintained for long periods of time even though there was little indication of cash income.

Coincident with the economic conditions during this period, investigational work at the experiment stations was largely concerned with projects pertaining to quantity production, and little consideration was given to the matter of costs and quality. As a result many practices that were developed and considered scientifically sound, based on such an economic or lack of economic background, are found to be no longer satisfactory under present systems where costs of operation and consumer's demand for quality in product are factors of foremost consideration.

An up-to-date program of research in agriculture as it pertains to present-day practices on the farm and in the home must not only give the same consideration as formerly to quantity of product, but is further complicated by the demand that results must be interpreted on a basis where the economics of production and the quality characteristics of the product are properly evaluated. In the promotion of research at Massachusetts Agricultural Experiment Station it has been the hope to maintain this desirable balance, and the progress made during the last year on the several projects under investigation is reported in the following pages.

DEPARTMENT OF AGRICULTURAL ECONOMICS

Alexander E. Cance in Charge

Consumer Demand for Apples. (Lorian P. Jefferson). The study of the consumer demand for apples has been divided into three parts. The first two sections, "The McIntosh Apple on the New York Market" and "A Study of the Consumer Demand for Apples", have already been published as Bulletins 243 and 250 respectively. The third section deals with the competition between apples and other fruits, and between different varieties of apples. The data for making these comparisons have been secured from public and private records, and much of the statistical work has already been done. The study will be completed in 1930.

The Economic Worth of Different Varieties of Apples. (Lorian P. Jefferson). This project, which has been under way for several years, has still two years to run. Data are being secured for a series of seasons, numbers of trees, yields by grades, and prices, looking to a determination as to which varieties are the most profitable for Massachusetts growers. While the statistics already secured have been tabulated, no summary has yet been made nor has any attempt been made to draw conclusions.

The Nature of Consumer Demand for Poultry Products. (Lorian P. Jefferson). This study is based on data collected from consumers and retailers, and should supply information as to the type of demand in specific markets through the State and thus be of use to both producer and dealer. The gathering of this material has not yet been completed.

Part-Time Farming. (David Rozman). The field work in connection with the project on part-time farming is now completed, and the material is being prepared for publication. Three different areas were investigated.

A house to house survey was carried on in the town of Holden with a view to determining the extent and relative importance of part-time farming in a rural community. As a result it was found that of 585 operators engaged in some kind of agricultural activities in the town of Holden, 519 were part-time farmers, and only 66 bona fide farmers. Part-time farmers contributed 42.6 per cent or almost one-half of the total value of agricultural products raised in Holden.

A second part of the study was carried on in the Lowell and Taunton areas represented by towns situated in the vicinity of these industrial centers. The main object of this part of the investigation was to determine the economic and social set-up of a representative group of part-time farmers. To this end a number of part-time farmers in both areas were visited with a detailed questionnaire taking records of their occupations, date of settling on the land, extent of farming operations, living conditions, and earnings both on the farm and outside of it. A total of 115 records was obtained in the Lowell area and 84 in the Taunton area.

The data obtained in this study portray an important feature of Massachusetts agriculture and have a special bearing on the problems of land utilization, food supply, and agricultural competition in the State.

Prices of Eggs and Poultry Products. (A. H. Lindsey). Until September 1 this project was under the leadership of H. W. Yount, who completed the work on the first two parts. Data have been gathered and tabulations and correlations completed for part three. Eggs were purchased in the

Boston market in April and August to supplement November data, as quality factors do not have the same relation to price at different seasons of the year. Price factors as determined in the study have been used in forecasting the price of eggs throughout the year.

Wholesale price quotations on the Boston market form the basic material for the study. The trend of egg prices since 1904 has been upward to 1916 and sharply upward to 1920. Since 1920 the trend has been downward, declining more abruptly after 1925. Although consumer's purchasing power has been increasing since 1920, the increasing receipts have been such as to cause a decrease in the corrected prices to a point below the price in the period ending 1916.

The seasonal movement shows a definite change since 1920. The period of high prices in the fall occurs earlier, and the decline from the high period to the low point of prices is more rapid than formerly.

Prices are determined by the operation of a number of factors. The importance of the various factors changes during different periods of the year. From April to November, during the period of rising prices, demand factors have a greater influence in price determination than supply factors. In the same way, during the period of falling prices from the third week in November to early in April, the supply factors are dominant.

The Study of Competitive Factors Influencing the Supply of Market Milk and Cream in Massachusetts. (A. E. Cance). Very little has been done on this project during the year owing to lack of time. During the year 1930 it is hoped to make a study of the demand for special milk in certain cities and towns in Massachusetts and to make a survey of the changes in the local supply areas, with a view to a better understanding of the effect of prices and demand on local milk production in Massachusetts.

DEPARTMENT OF AGRICULTURAL ENGINEERING

C. I. Gunness in Charge

Investigation of Apple Storages. (C. I. Gunness). The purpose of this investigation is to determine what is a satisfactory and economical storage house for McIntosh apples. A study of weather data and soil temperatures indicates that a common storage without artificial cooling can not be depended upon to provide sufficiently low temperatures to give proper storage for an early variety of apple like the McIntosh. The use of ice in cooling an insulated storage has been found to reduce the temperature about 10° when fans are used to circulate air over the ice. It is quite evident, however, that under present labor conditions it is not practical to use ice for artificial cooling in competition with mechanical refrigeration. During the present season an investigation is being carried on in cooperation with the Department of Pomology on the maximum temperature at which apples can be stored satisfactorily. Three lots of apples were stored at 45°, 40°, and 32° from picking time until December 1. The apples were then all placed in the 32° room for the balance of the season. No results are available as yet. Another phase of the investigation deals with the efficiency of different floor materials as insulators.

Fertilizer Distributors. (C. I. Gunness). A study of two types of broadcast distributors indicates a great difference in the uniformity of application by the various machines. No results can be given at this time as additional machines are to be tested, and all are to be tested with a variety of materials.

DEPARTMENT OF AGRONOMY

A. B. Beaumont in Charge

Nitrogen Assimilation by Havana Tobacco. (A. B. Beaumont). Two nitrate salts, four ammonium salts, ammonium nitrate, and fifteen organic nitrogen compounds were used. In the selection of organic carriers preference was given those amino acids reported as constituents of cottonseed, since cottonseed meal is the principal carrier of nitrogen in Connecticut Valley tobacco fertilizers. Cottonseed meal, itself, was used. Several series of plants were grown in non-sterile and sterile water and sand cultures. Analytical data on the chemical composition of the web of the leaf were obtained for plants grown in non-sterile water cultures. (Analyses were made by P. R. Nelson of the Chemistry Department.)

Taking yield data, growth characteristics, and chemical composition as criteria of assimilation, it is concluded that, of the various nitrogen compounds studied, the nitrates are the most readily assimilated by Havana tobacco, with urea, ammonium salts, asparagine and cystine next in order of assimilation. Of the various amino acids of cottonseed meal, only one, cystine, showed any appreciable assimilability; and cystine is said to be present in cottonseed in small amounts only. Cottonseed meal itself, or its hydrolyzed products, gave no evidence of being assimilated in the unchanged form. Evidence points toward the need of ammonification and nitrification of this organic nitrogen carrier before it can be fully assimilated by Havana tobacco.

Relation of the Form of Nitrogen to Root-rot of Havana Tobacco. (A. B Beaumont). Ammonium salts and certain amino and amide compounds have been found toxic to Havana tobacco in varying degrees. Browning and rotting of the roots and dying and dropping of the lower leaves were symptoms that accompanied this toxicity when the plants were grown in unsterilized media and containers. Tobacco grown under sterile conditions, but with the same forms of nitrogen, produced clean white roots. This is taken as evidence that the symptoms mentioned are secondary rather than primary effects of the form of nitrogen used.

Plants grown in unsterilized solutions containing nitrogen as sodium or calcium nitrate or urea produced healthy roots of a white or slightly brownish white appearance. Mixtures of nitrates and ammonium salts were toxic in proportion to the concentration of the latter. Nitrate nitrogen tended to counteract the ill effect of ammonium nitrogen on tobacco. In view of the data obtained, the toxicity of ammonium salts and certain organic compounds cannot be satisfactorily explained on the ground of either physiological acidity or hydrogen-ion concentration. Rather, it seems that improper metabolism caused by poor assimilation of nitrogen offers the best explanation of all but the extreme cases of toxicity.

Nitrogen Assimilation by Grasses and Clovers. (A. B. Beaumont). Data secured thus far indicate that nitrogen in the form of nitrate, ammonium salts, and urea is assimilated by the common tame grasses. No distinct differences in growth in the respective media have been obtained, as was the case with tobacco. Some, but inadequate, evidence has been obtained that clovers assimilate nitrogen directly from nitrates and urea but not from ammonium salts.

Ecological Study of Pasture Vegetation. (A. B. Beaumont). Further data have been obtained on the effect of lime and fertilizer nutrients on the growth of pasture vegetation. Yield records have been secured from certain plots; but on account of the excessive summer drought, differences which have appeared in other seasons did not show in the figures. In a new experiment with different forms of nitrogen applied as top dressings, the quick response of pasture grasses to nitrates, ammonium salts, and urea was very evident. Response to calcium cyanamid was slow. Subnormal rainfall may have been a significant factor in the behavior of the cyanamid. From our several experiments with nitrogen compounds it is very clear that comparatively large amounts of nitrogen do not eliminate white clover from the pasture flora.

Alfalfa Variety Tests. (A. B. Beaumont and R. E. Stitt). Further evidence has been obtained which shows that certain varieties of alfalfa originating in southern climates are not winter-hardy in Massachusetts. Tentative ranking of ten varieties grown in Test No. 1, in decreasing order of hardiness after two winters, is as follows:

1. Hungarian
2. Grimm, Ontario Variegated, Utah, Kansas, Dakota 12
3. Cossack, Argentine
4. Arizona, Ladak

No outstanding differences have appeared which could be attributed to fertilizer and lime treatments. At this stage of the test, it is very evident that varietal or strain differences are much more significant than are differences in fertilizer treatments within the range studied.

In Alfalfa Variety Test No. 2, 19 strains were seeded in 1928. The seasons' work on this test support the results from Test No. 1. A third test field of alfalfa varieties was started in August 1929. This is part of the extensive testing of legume varieties being conducted by this Station in cooperation with the Bureau of Plant Industry of the United States Department of Agriculture.

Tests of Varieties of Soy Beans and Field Peas. (A. B. Beaumont and R. E. Stitt). Twenty varieties of soy beans were grown from seed furnished by the Bureau of Plant Industry. Dunfield, Illini, Medium Green, Harbinsoy, Ito San and Habaro produced the largest yields of hay, but there were big differences in the quality based on size of stem. Large differences were also obtained in yield of seed, habit of growth, and other characteristics.

Five varieties of Canada field peas were grown. Planting time was delayed on account of the heavy rains of May. The plots were abnormally weedy and results are of little significance. Chang and Wisconsin produced the most hay, and O. A. C. 181 and Wisconsin the most seed to the acre.

The Value of Cover Crops for Onions. (J. P. Jones and M. E. Snell). The work on this project was begun in 1925. The plan has been to seed several cover crops on different plots at the last shove-hoeing and by comparison with adjacent plots without cover crops determine the effect on yield and quality of onions. Four years' records are now available. Considering the average effect on yield, red clover and rye appear to have been injurious, while crimson clover, timothy and redtop have been without effect. In 1928 and 1929 crimson clover and redtop increased the yield by 19 and 14 per cent respectively, but this was offset by decreased yields in the two previous years. A more consistent positive response is necessary before any of the cover crops thus far tested can be recommended as having a favorable influence on the yield and quality of onions.

Sulfate versus Muriate of Potash for Onions. (J. P. Jones and M. E. Snell). To answer the question frequently raised by growers as to the relative merits of sulfate and muriate as sources of potash for onions, the Station has conducted a comparative test of these two materials during the past four years. Summarizing the results for the entire period of the experiment, sulfate of potash gave an average yield of 137 bags per acre, while muriate gave 136 bags. In 1929, the year in which the onions were least affected by troubles such as blast, 242 bags per acre were obtained with sulfate of potash as contrasted with 250 bags with muriate, an insignificant difference. From the standpoint of growth of onions, it appears to make little difference which of these two forms of potash is used. In case of planning to grow tobacco on the land in the near future, it is perhaps best to fertilize with sulfate of potash to avoid any harmful effect on the burn of the tobacco frequently attributed to the chlorine carried by muriate of potash.

Lime in Relation to Onion Growth. (J. P. Jones and M. E. Snell). The experiments conducted during the past five years have shown lime to be almost indispensable in the successful growth of onions on acid soils. This has been demonstrated both on the Experiment Station farm and on several farms in the Connecticut Valley. The average of four years' results on the Experiment Station farm showed an increase of about 70 per cent in yield of No. 1 onions. Two tons of lime per acre have been about as effective as higher applications. In the last two years there has been a decline in the percentage response to lime. For instance, in 1926 and 1927 an increase of 87 and 96 per cent, respectively, was recorded for two tons of lime per acre, while in 1928 and 1929 the increase was only 51 and 33 per cent. Since the application was made five years ago, these results might indicate an exhaustion of the lime. On the other hand, this same trend is evident on the plots which received seven tons of lime per acre, and it scarcely seems possible that lime should be lacking with so large an initial application, even at the end of five years. The difference is believed to be due to a variation in seasons. In 1928 the blast hit the onions quite early, before the bottoms had begun to show appreciably. The tops were killed rapidly, and the injury seemed to be equally severe on limed and unlimed plots. The limed plots produce bulbs earlier and hence have an advantage when the blast occurs some time after bulbs have begun to form, as was the case in 1927; but in 1928, with the blast appearing just about at the beginning of bulb formation, this advantage was greatly minimized. In 1929, however, there was no blast, and differences in earliness of bulb formation were not so important because quite favorable growing conditions prevailed throughout the season, allowing ample opportunity for the bulbs on both the limed and unlimed plots to mature. While 33 per cent increase in 1929 on the limed plot seemed small in comparison to that of previous years, the actual increase in yield per acre was approximately as large an any yet obtained.

When it was recognized that considerable lime must be added to acid soils to grow onions satisfactorily, there was some apprehension that severe damage might result through black root-rot injury should the grower wish to plant the ordinary strains of tobacco on his highly limed onion land. The Station therefore undertook some experiments looking toward the successful growth of onions at a soil reaction sufficiently acid to prevent any serious injury by black root-rot in case tobacco was grown later. Superphosphate has been credited by the Rhode Island Experiment Station and others as having an effect on acid soils, similar in some respects to that of lime. Large applications of superphosphate, alone and in combination with small amounts of lime, have been tried for the last two years. There is evidence that 500 to 1000 pounds of agricultural lime per acre in combination with 600 to 1000 pounds of superphosphate in addition to that in the regular fertilizer may be as effective as two tons of agricultural lime; but superphosphate alone, even in large applications, has not given satisfactory results. It has also been learned in this connection that onions can be grown satisfactorily at a reaction of pH 6.0. If the lime used in growing the onions has not raised the pH above this point, little injury may be expected from black root-rot should tobacco be grown on the land subsequently, especially if the soil is well drained.

Fertilizer Ratios for Onions. (J. P. Jones and M. E. Snell). This experiment was begun in 1925 with the idea of getting some estimate (1) of the relative amounts of nitrogen, phosphorus, and potash required by onions, (2) of the merits of fractional application of nitrogen, and (3) of the value of organic forms of nitrogen. All fertilizers have been applied at the rate of 2500 pounds per acre. The results at present show that increasing the phosphorus without at the same time increasing the potash is unprofitable. For instance, the 4-12-4 has given no better results than the 4-8-4, but the 4-12-8 has given an average increase of 18 per cent in yield over the 4-8-4 during the past four years. However, in 1929 the 4-12-8 did not give appreciably better results than the 4-8-4 or the 4-12-4, the large average increase being due to the large difference obtained in the three previous years.

The data on the amount of nitrogen indicate that a fertilizer carrying 4 per cent ammonia, applied at the rate of 2500 pounds per acre, will provide adequately for the first application. If necessary more nitrogen can be added later as a top-dressing, either in the form of fish or of nitrate of soda. Increasing the ammonia from 4 to 6 per cent by top-dressing has improved the yield by about 12 per cent over applying the entire 6 per cent in the first application of fertilizer. It is interesting to note that during the dry season of 1929 top-dressing with fish gave no increase in yield, while top-dressing with nitrate of soda gave a 13 per cent increase.

The 4-12-8 was used in the comparison of organic and inorganic forms of nitrogen. On one set of plots 50 per cent of the nitrogen applied came from tankage, 25 per cent from nitrate of soda and 25 per cent from ammo-phos; on the other set, about 20 per cent of the nitrogen was from calcium nitrate and the remaining 80 per cent from ammo-phos, both inorganic forms of nitrogen. With these materials differences were obtained which indicate that having some of the nitrogen in an organic form is preferable. However, the use of other sources of nitrogen might show the difference between the organic and inorganic forms of nitrogen to be less significant.

Onion Breeding. (J. P. Jones and M. E. Snell). The onion breeding work was continued in 1929 along the same line as reported last year, with major emphasis on selecting, inbreeding and mass breeding several strains of the yellow globe and Japanese set onions. In cooperation with G. B. Snyder, some effort was made to test a number of other varieties in addition to the yellow globe. This phase of the work should be pushed more vigorously during the coming year.

Influence on Onions of Rate of Seeding and Spacing Between Rows. (J. P. Jones and M. E. Snell). It was observed during the season of 1928 that the severity of the injury resulting from blast was greatly influenced by the thickness of the stand of onions. As a part of the studies made in connection with the blast problem, an experiment was laid out in 1929 to determine definitely the extent to which thickness in the row and space between the rows affected blast. There was no blast in the summer of 1929; hence nothing was learned regarding this. It was, however, possible to observe how such differences in planting affected yield and quality of onions in the absence of disease. Seeding at the rate of 3.5 pounds per acre impaired the yield out of proportion to the improvement in quality; seeding at the rate of 6.8 pounds per acre increased the yield, but not sufficiently to counteract the effects of reduction in quality. Rows 13 inches apart were found to give larger yields than those 15 or 18 inches apart, and there was little difference in quality. With seed showing a germination of 99 per cent as this did, it was concluded that for practical conditions seeding at the rate of between 4 and 5 pounds per acre, in rows 13 inches apart, will give the best returns.

In this experiment, as well as in some of the other onion experiments, counts were made of the number of plants per foot of row about the first of August. It was estimated from these data that only about 50 per cent of the seed planted actually produced plants that are likely to mature.

Relation of Aluminum Compounds to the Ill Effects of Certain Crops when Grown in Rotation. (J. P. Jones and M. E. Snell). This project includes the rotation and cover crop experiments and also that dealing with the specific effects of other crops on tobacco. In 1929 the work was redirected, looking toward a better understanding of some of the unusual results obtained with rotations. Among other things, consideration has been given to the possible relation of aluminum compounds to the depressing effect of some of the preceding crops on the yield and quality of tobacco.

Field results:—The results in 1929 were not greatly different from those of previous years. The animal husbandry rotation consisting of corn, hay, and tobacco (the tobacco following hay) again produced a very poor crop of tobacco. The first four years timothy alone was seeded in the corn for hay, but during the last two years the plots have been divided, with timothy on the west and clover on the east halves of the plots. It was thought that the clover might improve the growth of tobacco in this rotation, but on the contrary the tobacco has been poorer after clover than after timothy two years in succession, 1928 and 1929. The tobacco was fertilized with 3500 pounds per acre of a 5-4-5 fertilizer mixture and approximately 10 tons of manure,—a more liberal treatment than was given the continuous tobacco plots which yielded satisfactorily. Corn in this rotation has generally grown well; but the timothy hay, although adequately top-dressed with fertilizer, has always been more or less of a failure. Clover, on the other hand, has grown vigorously, yielding in some instances double the amount of hay obtained from timothy.

In the cash crop rotation consisting of potatoes, onions and tobacco (tobacco following onions), the tobacco has always been superior to that produced in the animal husbandry rotation but not usually comparable to that grown in continuous culture. In 1928 the tobacco in this rotation yielded about as well as that on the continuous no-cover plots, but in 1929 the comparison was less favorable. The onions have never been especially successful, while the potatoes have been good in some years and poor in others. In 1929 a low yield of both onions and potatoes was obtained.

The comparison of timothy, redtop and rye as cover crops for tobacco was made again in 1929. The results for the past year showed timothy to be as satisfactory as either redtop or rye, and the yield of tobacco to be about as high as that on the plots without a cover crop. During the four years tested, redtop and rye have both given as good yields of tobacco as the no-cover plots. Timothy, on the contrary, has depressed the yield of tobacco three years out of six, but during the last three years it has given results just about as good as the no-cover plots.

The plots treated with manure in addition to the commercial fertilizer produced a very satisfactory crop during the season of 1929. Taking the six-year records available from these plots, very slight superiority can be claimed for the manure in comparison with a regular tobacco fertilizer. It has, however, been possible to reduce the fertilizer about 25 per cent without impairing the yield or quality of the tobacco. In response to requests from growers, the plots were divided in halves in 1929 and a sawdust stable manure was compared with the well rotted manure from the Station stables. The sawdust manure was obtained from the Quonquot stables where sawdust is used exclusively and liberally for bedding. This manure when in a pile looked more like sawdust than manure. The tobacco grew about equally well on the two types of manure. No injurious effect was noted from the sawdust. One year's results are not sufficient, however, to make any claims about the use of this manure year after year.

Tobacco after corn grew quite vigorously in the season of 1929 but yielded only 1692 pounds per acre in comparison with 1785 pounds after hay and 1890 pounds after tobacco. After onions and potatoes the yields were about the same but somewhat lower than after corn and hay. This is an unusual result because in previous years better yields have been obtained after onions and potatoes than after corn and hay.

In 1929 brown root-rot affected the roots of the tobacco but slightly on the cover and no-cover crop plots but did injure the roots of the tobacco in rotation with corn and hay very severely and to a less extent that in rotation with potatoes and onions.

In the greenhouse, with water cultures, aluminum has been found to produce an effect on tobacco roots similar to that of brown root-rot in the field. Thinking that aluminum in the soil might be a factor in causing brown root-rot in the field, treatments were made on the rotation plots to eliminate any effect of soluble aluminum. These treatments consisted of large applications of superphosphate, which experiments at other stations have proven to be successful in counteracting the injurious effects of aluminum. The results were not particularly encouraging. Brown root-rot was just as severe where the superphosphate treatments were made as where they were not. The yield was not increased by the superphosphate, which is contrary to experience with similar treatments on other plots in the absence of brown root-rot. It might be said from this year's experience, if it can be assumed that superphosphate renders soluble aluminum inactive, that the brown root-rot found in the field is not caused by an excess of soluble aluminum, and that it is a different type from that observed in the greenhouse water cultures as resulting from aluminum injury.

Soil nitrate determinations were made during the growing season of 1929 to see whether plowing under carbonaceous residues had reduced the available nitrogen, as found by other experiment stations. The data obtained are in agreement with those of previous years in showing no case where the residues turned under in the rotations have reduced the available nitrogen to the point where it limited the growth of tobacco.

Quantity of Nitrogen and Phosphorus for Tobacco. (J. P. Jones and M. E. Snell). The phase of this experiment dealing with the amount of nitrogen required in growing tobacco was started in 1926. The recommendations which seem justified from work on the experimental plots to date are: (1) In the absence of barnyard manure, 150 pounds of ammonia per acre is the minimum that should be considered in fertilizing tobacco; (2) a somewhat better yield has been obtained each year with 200 pounds of ammonia per acre than with 150 pounds, and for many fields the larger application may be nearer the optimum; (3) although in previous years 250 pounds of ammonia per acre produced slightly superior yields, in 1929 it gave no better yields than the 200-pound treatment; and it has been concluded that this large application will prove profitable only in unusual situations.

Among the observations made on tobacco, it was noted that the reduction in growth due to the deficient nitrogen was always apparent before the typical yellow color signifying nitrogen starvation. In 1928, a rainy season, the yellow color was found much earlier than in 1929, a dry season. Although reduced growth could be seen readily on the low nitrogen plots in 1929, yellowing of the leaves was scarcely perceptible even at the time of harvest.

In the experiments with quantity of phosphorus, attempt has been made to measure the stimulative effect on the growth of tobacco of large applications of superphosphate, rather than to determine the optimum nutrient requirement of tobacco for phosphorus. During the first season, 1928, when one-half, one, two, and four tons of superphosphate per acre were applied in addition to that in the regular tobacco fertilizer, notable increases in yield were obtained, the maximum being from the two-ton treatment. In 1929 much larger yields were obtained, but there was no response to the excessive applications of superphosphate. In another experiment, however, the yields were markedly stimulated by four tons of superphosphate. A very interesting feature of these experiments has been the observation on maturity. Contrary to what is generally expected from excessive applications of phosphorus, there has been no evidence that the tobacco has matured unusually early or any differently from that not receiving the extra phosphorus.

The Magnesium Requirement of Certain Common Crop Plants. (J. P. Jones and M. E. Snell). This experiment was started in the season of 1929 and is a redirection of previous work which had shown a magnesium deficiency in the soil of one of the old experimental fields at the Station, illustrated by certain symptoms on both corn and tobacco. The work as now outlined consists of an attempt to observe the symptoms of a lack of magnesium on several of the commonly grown crops, such as onions, clover, timothy, alfalfa, and potatoes. The season was too dry in 1929 to permit a satisfactory growth of these crops; hence the observations made are not considered sufficiently satisfactory to draw conclusions at this time. It has also been proposed in connection with this work to make some chemical studies of this and other soils, hoping to account more definitely for the lack of magnesium. Progress is being made on this phase of the work, but no results can be included in this report.

DEPARTMENT OF BACTERIOLOGY AND PHYSIOLOGY

G. E. Gage in Charge

Nitrogen-Fixation in Relation to Legumes and Non-Legumes under Defined Agronomic Conditions. (James E. Fuller). This project has been followed out as outlined for the last year: namely, to study soils of different units to determine the ability of these units to fix atmospheric nitrogen; to isolate organisms from the units and study the distribution of nitrogen-fixation organisms as compared with the nitrogen-fixation power of the soil units; and lastly, to study factors which may influence the presence and activity of nitrogen-fixing organisms isolated in the studies. The preliminary phase of this project has been completed and has been written up and accepted for publication by *Soil Science.* It will appear in the next May or June issue of that journal. The first part of this study was carried on by Dr. Leon A. Bradley and was taken over in 1928 by Dr. James E. Fuller. A summary of this preliminary investigation as carried out on an experimental field (Field A) divided into twenty-four plots, has furnished the following information.

Four definitely planned experimental conditions were established for the defined agronomic work:

1. Units planted with legumes and receiving fertilizer.
2. Units planted with legumes and not receiving fertilizer.
3. Units receiving fertilizer but not planted with legumes.
4. Units not receiving fertilizer and not planted with legumes.

From this summary there appears to be sufficient nitrogen-fixation in the soil of Field A to account for the nitrogen reserve. The nitrogen-fixation in the experimental field is correlated with the presence of a strain of Azotobacter capable of fixing substantial quantities of nitrogen when cultivated in pure culture in a nitrogen-free medium. Nitrogen-fixation and the distribution of the Azotobacter appear to have remained reasonably constant over a three-year period. The growth of the legume and non-legume crops has not influenced nitrogen-fixation or the distribution of the Azotobacter. The hydrogen-ion concentration of the soil of the experimental field does not appear to be the controlling factor in the nitrogen-fixation or the distribution of the Azotobacter. The data as accumulated in this study have furnished considerable information which may later be placed on a basis for the establishment of practical methods by which the nitrogen-fixation organisms *naturally present in soil* may be stimulated to greater activity.

Laboratory Service. (Ralph L. France). More than one thousand examinations of samples were made by the department during the past year. Of this number, seven hundred were control tests of various town milk supplies in the Connecticut Valley. In many cases monthly control tests are made, and in other cases the testing is done at different times during the month. At the present time the activities in this phase of the laboratory work are somewhat limited because samples can be transported only short distances. Then, too, the Massachusetts State Department of Health carries on activities especially for those dairies and town health departments located in the Boston or metropolitan district. Many samples from private water supplies have been submitted to the laboratory for examination. These have been for complete bacteriological and chemical examination, for the most part, to determine the purity of the water in question. It is of some interest to us from the standpoint of public health to note that nearly 50 per cent of the private supplies were found to be unsafe. This indicates the need of more active education in the construction and location of private water supplies. It also indicates the need of a sanitary survey of water supplies as regards those located on private property.

The sale of legume cultures has materially decreased during the year. This is no doubt due to the activities of certain commercial concerns which are supplying cultures free to purchasers of legume seeds in bushel lots.

Other services rendered by the laboratory are:

1. Bacteriological analyses of food and food products, milk and milk products, and water.
2. Chemical analyses of milk and water.
3. Preparation and distribution of viable and efficient cultures of nitrogen-fixing bacteria for leguminous crops.
4. Testing of nitrogen-fixing bacteria for quality.

5. Bacteriological examinations concerning sewage disposal.
6. Bacteriological examinations of swimming tank waters for purity.

Studies on the Indol Tolerance of the Colon-Aerogenes Group of Bacteria as a Possible Means of Differentiating Fecal and Non-Fecal Strains Occurring in Drinking Water Supplies. (Ralph L. France). The results to date are very promising and it is hoped that the study will supply a more accurate method of testing water for fecal contamination.

The laboratory is now in its second year of service and the indications are that it is well established and conducted for the kind of work assigned to it. This type of supplementary investigational program will aid materially in the value of the service.

DEPARTMENT OF BOTANY

A. Vincent Osmun in Charge

Tobacco Diseases. (W. L. Doran).

Black Root-Rot. A paper on the effects of soil temperature and reaction on growth of tobacco infected and uninfected with black root-rot has been accepted for publication in the *Journal of Agricultural Research* for December 1, 1929.

In the field experiments, the pH values of soil in limed plots have remained practically unchanged at about 6.0 for the past four years. Neither alfalfa nor timothy, grown two seasons on limed plots, has resulted in soil significantly more acid than has continuous tobacco. Of the acidifying treatments of limed soil, the most effective were sulfuric and orthophosphoric acids applied together in two successive years, and sulfur (400 lbs. per acre) applied in two successive years. The application of any of these treatments in only one year (1926) had but slight effect, if any, on soil reaction after 1927. Examination of roots indicated that black root-rot in these plots was suppressed in proportion to the effectiveness of the acidifying applications.

Yields on unlimed plots without acidification and with tobacco grown continuously were 28 per cent greater than on limed plots (last limed in 1923). Yields on limed plots were increased by all the acidification treatments as compared with yields on limed plots without acidification. Sulfur (200 lbs. per acre) applied in 1926 and 1927, and sulfuric and orthophosphoric acids applied together in the same years gave the greatest increases.

Investigation of the use of various chemicals for the prevention of black root-rot and other soil-borne diseases of tobacco seedlings has continued. Acetic acid treatment of the soil was tested in several commercial seed beds. In every case the treatment resulted in suppression of weeds and successful control of both damping-off and black root-rot. It compared favorably with steam sterilization against which it was checked.

Tests with monochloracetic acid were not encouraging. Interesting and promising results were obtained with pyroligneous acid. Experiments were conducted with the object of adding to our knowledge of the effect of soil conditions on the efficiency of acetic acid and formaldehyde as soil disinfectants.

Study was made to determine whether the inhibiting effect of acid soils on *Thielavia basicola* may be directly due to some other factor than hydrogen-ion concentration, more especially active aluminum. Results indicate that aluminum sulfate is about as effective as sulfur and sulfuric acid in acidifying soil and in suppressing the black root-rot fungus.

Earlier experiments indicated that phosphoric acid is markedly favorable to the parasitism of *Thielavia basicola* and that its influence may be as great as that of soil reaction, or greater. The effect of this chemical on black root-rot, growth of tobacco, and soil reaction is now being studied in a new series of pot experiments.

Brown Root-Rot. Field studies have continued on the plots originally planned for investigation of black root-rot. In general, there was practically no brown root-rot on plots in continuous tobacco since 1921; some brown root-rot occurred wherever tobacco followed either timothy or alfalfa, but was somewhat more severe in limed plots following timothy. The presence of brown root-rot was generally accompanied by reduction of yield, but a consistant relation between disease and yield was not always found.

On the theory that timothy sod is injurious to tobacco because of the large amount of cellulose and the low amount of available nitrogen present, Johnson and coworkers of the Wisconsin Station recommend applications of nitrogen where tobacco follows timothy. In order to determine the effect of nitrate (calcium nitrate), and the time of its application to timothy sod, on tobacco and on brown root-rot, a series of pot experiments was conducted. From these it may be concluded that heavy applications of calcium nitrate to timothy sod reduce the severity of brown root-rot; and that the nitrate increases growth much more when applied to brown root-rot soil than when applied to soil which does not contain the cause of brown root-rot.

Assuming a hypothetical relation between brown root-rot and activities of soil organisms resulting in a lack of nitrogen or in the formation of substances (undetermined) toxic to tobacco, it would seem possible that certain inorganic salts applied to the soil might affect the disease through their toxicity to the organisms or by chemically inactivating certain toxic substances. Experiments based on this theory are under way, but it is too early to report definite results.

Control of Diseases of Greenhouse Vegetables. (E. F. Guba, Waltham).

Leaf-Mold of Tomatoes. Work on this disease during the last year has been concerned mainly with house management as a means of control. The conidia of the causal fungus germinate at a relative humidity of 100 per cent, which in the greenhouse is attained on the leaf surfaces when the atmospheric humidity is above 85 per cent. Proper adjustment of air circulation, water and heat is necessary to maintain conditions unfavorable to conidial germination, and this ordinarily involves much labor and attention by the operator. In this investigation equipment for the automatic control of temperature and humidity has been employed. In the light of knowledge previously gained in laboratory study of the causal fungus and observations in the greenhouse, a set of house management practices was evolved to provide proper conditions for the control of leaf-mold. Experiments were conducted for comparison of "good" and "bad" growing conditions as related to control of the disease. Proper management resulted in decreasing leaf infection about 70 per cent and yield of fruit was increased 18 per cent.

Downy Mildews of Cucumber and Lettuce. (W. L. Doran). The first appearance of downy mildew on cucumbers in the field was recorded on August 19, only a few days later than for the last five years,—and this despite the extremely dry summer, in which neither onion nor potato mildew was observed in this region. The disease was no less severe in some fields where cucumbers had not been grown for at least three years previously than on fields where cucumbers were affected with the disease last year.

Lettuce mildew rarely occurs in the field here except in cool weather in fall. Attempts to maintain the fungus on infected plants (Belmont variety) set in the field in May failed, probably because of the warm, dry weather. Observations indicate that high air temperature constitutes an important natural defense against this disease in the field.

In the greenhouse, work continued on the relation of management and the use of fungicides to the control of these diseases. Experiments to determine whether potash and lime applied to the soil tend to decrease susceptibility of cucumber plants to attack by downy mildew produced only negative results.

Pseudoperonospora of cucumber and Bremia of lettuce were successfully grown for several weeks on detached cotyledons of host seedlings floated in a 5 per cent solution of sucrose in Petri dishes. It is thus possible, by occasional transfers, to maintain these fungi when conditions in the greenhouse do not favor their growth.

Study of over-wintering of downy mildew of cucumber added nothing to previous knowledge of this phase.

Eradication of Nematodes in Greenhouse Soils. (L. H. Jones). Work previously reported has shown that a combination of acetic acid with calcium cyanide will eradicate nematodes. Of considerable importance is the fact that two treatments with this combination must be used, with an interval of about seven days between the treatments. The rôle of the acetic acid in the combination chemical is apparently that of a carrier for the lethal cyanide. The effect is to maintain the fairly volatile cyanide gas in the soil much longer than it would ordinarily persist if the acetic acid were not used. If this same principle could be applied by using a dry chemical in place of the liquid acetic acid the idea would have a better opportunity for adoption in agricultural practice. Paradichlorobenzene, the P. D. B. used in eradicating peach borers, seems to fulfill the same rôle as acetic acid. It is a dry chemical and when mixed with calcium cyanide the combination remains a true mixture. There is no caking and once a uniform mixture is attained it remains as such. One treatment with this combination reduces the numbers of nematodes considerably, but eradication is not obtained unless two treatments are used with an interval of one week between applications. The use of the paradichlorobenzene with calcium cyanide has been tried by varying the proportions of each chemical and also the amount applied. In general the results indicate that a 1:1 ratio is the best, and three grams of the mixed chemicals for a six-inch pot of soil proved the most efficient rate of application. Before this method can be demonstrated on a commercial scale, there are certain problems that must be solved by the laboratory method.

Eggplant Wilt. (E. F. Guba, Waltham). Addition of chemicals to the hills at planting time, with the object of sterilizing the soil about the roots, gave no control of the wilt disease. Negative results were also obtained with the use of a paper mulch. Studies in several fields of the New York Purple variety indicate that the eggplant tolerates a high degree of soil acidity, and that this condition usually is accompanied by an insignificant amount of wilt. These findings point to the changing of soil reaction as a means of controlling wilt, and efforts are being directed toward this objective.

Onion Blast. Several departments cooperated in work on various phases of the problem presented by the disease of onions known as *blast.* A field survey and spraying and dusting experiments were conducted by A. I. Bourne (Department of Entomology) and W. L. Doran (Department of Botany). Weather conditions were unfavorable to the development of blast, and the trouble did not occur. Drought injury and thrips injury were severe in many fields. Because of the absence of blast and downy mildew, no data were obtained on the effect of dusts and sprays on these diseases. The joint effects of chemicals and mechanical injuries were such that it was concluded safe to spray six times with 4-4-50 Bordeaux, but not nine times: three times with 8-4-50 Bordeaux, but not five times; and six times with milk of lime, but not nine times. Copper-lime dusts proved more injurious than any of the Bordeaux mixtures.

L. H. Jones (Department of Botany) worked on the physiology of onion blast. Growing onions under conditions of reduced light and high humidity tended to reduce root growth and to produce tender tops. Subsequently, when exposed to hot sunshine and drying wind, these plants were injured in a manner resembling the condition known as blast.

Carnation Blight. (E. F. Guba, Waltham). The toxicity of fungicides to spores of the causal fungus (*Alternaria dianthi* S. & H.), the prevention of infection of potted plants which were artificially inoculated with spores of the pathogene, and the control of the disease in the field have been studied. In the toxicity tests with spores, naphthalene dust proved the most effective of twelve fungicides employed. In an experiment on the prevention of infection, five fungicides were used, each applied alone and in combination with fish oil. Calcium arsenate with fish oil and Bordeaux mixture with fish oil gave the best results. Results of a second experiment substantiated those of the first and indicated no advantage in the use of saponin as a spreader. Thirteen distinct treatments were compared in a spraying experiment in the field. Bordeaux combined with calcium arsenate and fish oil was the most effective of the fungicides used. Copper-lime dust and calcium arsenate proved the least effective. Calcium arsenate, alone or in combination with lime-sulfur, caused injury to the plants.

Forcing Gladiolus with the Aid of Artificial Light. (L. H. Jones). The embryonic flowers of the gladiolus are formed a few weeks after the corms are planted. Under normal out-of-door cultural conditions this period would be during the longest daylight exposures of the year. A preliminary pot experiment indicated that a marked increase in bloom could be obtained by supplementing the daylight of late fall and early winter employing 100-watt electric light bulbs.

An experiment based on this light factor in which four plots were used was set up in January, 1929. Black curtains separated the plots receiving artificial light from those receiving no artificial light at night. In each plot 195 corms were planted and a careful record was made of the number of flowering spikes and the number of flowers on each spike. The results showed that light had caused an increase of 63 per cent in the number of spikes and an average increase of 30 per cent in the number of flowers on a spike.

The time of year has considerable influence on the time interval from planting to flowering, and this time interval is increased by the use of artificial light. In these experiments artificial light retarded the date of flowering by approximately fifteen days.

The variety Crimson Glow was used in conducting this investigation.

Influence of Light Quality on Plant Growth. (A. V. Osmun). Preliminary experiments have been conducted to test the effect of so-called health glass (glass which transmits a considerable percentage of the ultra-violet rays) on plant growth and development. Plantings were made in a lean-to greenhouse in which one-half of the ordinary glass had been replaced by Vita glass. Radishes grown under Vita glass showed a gain of 71 per cent in weight of the entire plant and 124 per cent in weight of roots as compared with an equal number of plants grown under ordinary glass. Similarly, lettuce gained 76 per cent in weight and formed much more compact heads when grown under Vita glass. No consistent results were obtained with calendulas and pansies.

The Effect of Pot Structure on Soil Temperature. (L. H. Jones). A series of tests conducted with various types of plant containers has shown that the structure of the container has a marked influence on the temperature of the soil. The regulation three-inch standard clay pot will maintain a soil temperature as much as 20° F. below that of the air in a greenhouse on a hot day. On the other hand, a pot of vitreous material or a glass tumbler will maintain a soil temperature that lags only 1° or 2° behind the rise and fall of the air temperature.

Between these two extreme types of pots, the former very porous and the latter with no porosity, there are intermediate types of pots that maintain their soil temperatures according to the amount of moist area presented by the pot to the air in the case of the porous pots, or else the soil temperature will be influenced by the insulating value of the pot material in the case of the non-porous pots.

The cooling effect by evaporation of moisture from the outside of the pot persists as long as the pot is able to withdraw moisture from the soil to moisten its surface.

THE CRANBERRY STATION

(East Wareham, Massachusetts)

H. J. Franklin in Charge

Injurious and Beneficial Insects Affecting the Cranberry. (H. J. Franklin).

(a) Penetrol, an activating oil developed under the auspices of the Crop Protection Institute, was tried with nicotine sulfate and also with pyrethrum soap in tests to control the black-headed fireworm, with negative results.

(b) Dipple's oil was tested as a repellent against the cranberry fruitworm moth, with negative results.

(c) The relationship of birds to cranberry pests was studied somewhat. Birds were killed and the contents of their digestive tracts examined.

(d) Entomogenous fungi parasitic on the black-headed fireworm were cultured and disseminated on cranberry bogs to test the possibilities of practical control of the fireworm by the use of these fungi. Dr. William H. Sawyer, Jr., was in charge of this work. Practicable methods for growing the fungi in quantity were developed, but the results of field dissemination were not successful enough to make this method of control seem very practicable.

(e) Japanese beetle traps and baits were tried against the cranberry root grub beetle, with mostly negative results.

(f) The life histories of the cranberry black bug (*Plagiognathus repetitus* Knight) and the false blossom leafhopper (*Euscelis striatulus*) were studied.

(g) Various kinds of fish were tested as possible water indicators to be used when flooding cranberry bogs to determine readily when such flooding has become dangerous. This study gave very promising results. Dr. H. F. Bergman was in charge of this work.

(h) Profitable studies were conducted on the distribution and habits of the cranberry white grub (*Phyllophaga anxia* Lec.).

(i) Spray tests against the false blossom leafhopper, with nicotine sulfate and with pyrethrum soap, brought out very clearly the fact that the latter controls the pest much more effectively than the former, while the two insecticides used together caused considerable injury to the vines.

Cranberry Disease Work. (H. J. Franklin in cooperation with the Bureau of Plant Industry, U. S. D. A.). Dr. Neil E. Stevens of the Bureau of Plant Industry was at the Cranberry Station during much of the growing season and cooperated actively as usual in this work.

(a) Final and conclusive proof was developed that the false blossom disease is carried freely from diseased to healthy vines by the leafhopper (*Euscelis striatulus* Fall.) This is very important and should lead shortly to a much better control of this serious disease than has been achieved in the past. Other experiments gave little evidence, if any, that the cranberry black bug, cranberry spittle insect, sharp-nosed leafhopper (*Platymetopius magdalensis* Prov.), or springtails (Collembola) have anything to do with the spread of the disease. The history of the spread of this disease in Massachusetts was given further careful study to make it as complete as possible.

(b) Dr. Stevens continued and extended his studies of the relationship of weather to the keeping quality of the fruit, and his incubator tests of keeping quality.

(c) Dr. Stevens made studies of the relative thickness of the cuticle of the berries of many different varieties to see if this showed any correlation to varietal disease resistance. The study gave negative results which were, nevertheless, highly significant and of great importance.

Weather Observations with Reference to Frost Prediction. (H. J. Franklin in cooperation with the U. S. Weather Bureau).

(a) Reports of local weather observations made at 8 a.m. (Eastern Standard Time) were made daily by telegraph to the office of the Weather Bureau at Boston. General weather observations were made and recorded at 8 a.m., noon, and 8 p.m. and were reported on a card form to Boston daily.

(b) Further weather records likely to have a bearing on frost forecasting were accumulated from observing stations in North Harwich, East Wareham, Carlisle, Holliston and Worcester, as well as the regular cranberry observing stations at Marstons Mills, South Carver, Norton, Halifax, South Hanson, and Pembroke.

(c) Studies of observations already recorded yielded important new knowledge on this subject, making possible further definite improvement of the formulae for computing temperature minima. In the formulae thus modified, the dew-point and the reading of the wet bulb thermometer are the significant data mathematically combined.

(d) Forecasts of minimum bog temperatures were made in the frost seasons at noon and at 7 p.m. (Eastern Standard Time). These forecasts were distributed by the New England Telephone & Telegraph Company as heretofore, the cost of distribution being paid by the Cape Cod Cranberry Growers' Association.

Varieties. Dr. Sawyer made hydrogen-ion determinations of the foliage of many of the cranberry varieties at different times of the day and night and of the growing season. It was thought that this work might show a correlation between pH values and productiveness or disease resistance in cranberry varieties; but while the pH of the different varieties showed interesting variations, no very certain correlation of this kind was disclosed.

DEPARTMENT OF DAIRY INDUSTRY

J. H. Frandsen in Charge

A Study of Packaged Ice Cream. (K. E. Wright). This project has continued uninterruptedly during the year. Much work has been done as a check on preliminary conclusions reported in the last Biennial Report. Research work has also been done on several other phases of this problem. Considerable study has been made in an effort to determine just why a maximum drawing temperature of 25.5°F. seems necessary in the case of a 12 per cent fat, 10 per cent serum solids, 15 per cent sugar, and .45 per cent gelatin mix. A study of the rate of cooling samples drawn from the freezer at various temperatures indicated no difference as far as evolution of heat fusion and crystal formation are concerned.

From a study of the effect of aging on the texture of ice cream, the following conclusions have been drawn:

1. A high initial temperature in the aging period of the ice cream mix favored the development of greater basic viscosity.
2. The maximum viscosity was found to be imparted when the mix was held at a temperature of 80 to 100°F. for two to four hours, without agitation.
3. The whipping property was decreased as the viscosity increased.
4. The rate of melting was decreased as the viscosity increased. The manner of melt-down was also influenced by difference in viscosity.
5. The texture was improved as a result of greater viscosity development.
6. The influence of aging in ice cream has been attributed largely to the factors affecting crystallization of the gelatin portion of the product on the basis of the data obtained.

The Quinhydrone Electrode in the Dairy Laboratory. (Work started by A. W. Phillips and now conducted by K. E. Wright.)

Further study indicates that since different kinds of milk bacterial flora function in different ranges of pH, and since milk has a relatively high buffer value and perceptible changes in pH do not take place with appreciable additions of acid or alkali, the quinhydrone electrode determination of pH cannot be used for determining accurately the keeping quality of milk. This work agrees with conclusions reached by A. W. Phillips.

The Utilization of Frozen Fruits in Ice Cream. (M. J. Mack). This project, now in its second year, is being conducted in cooperation with the Department of Horticultural Manufactures. Fruits made available in a study of cold packing methods are being used in the manufacture of fruit ice cream.

The varieties of fruits which were found to be most satisfactory for freezing are likewise superior for use in ice cream. The optimum percentage of fruit in fruit ice cream was found to be approximately 15 per cent for cold packed strawberries; 8 to 10 per cent for raspberries, plus a suitable amount of raspberry extract; 15 to 20 per cent for peaches in combination with an extract; and 12 per cent for cherries. The desirable ratio of fruit to sugar in the pack used for ice cream making was found to be 2:1 and 3:1 for cherries and strawberries, and 3:1 for raspberries and peaches. Fruit frozen without sugar or with corn sugar as a substitute for cane sugar was unsuitable for use in ice cream.

The fruit should be added to the ice cream directly after the freezing operation is started in order to insure the maximum of fruit flavor and even fruit distribution as well as more rapid freezing and whipping of the ice cream. Fruit ice creams have a lower freezing point than plain ice cream and should be drawn from the freezer at a temperature at least 1 to 1.5°F. lower than is necessary for plain ice cream. Fruit ice creams cool faster in the freezer, whip faster, and require a shorter time of brine flow than does plain ice cream made from the same basic mix.

A Study of Frozen Sweet Cream for Use in Ice Cream. (M. J. Mack). Sweet cream of good quality can be stored satisfactorily in the frozen state during surplus periods for later use in ice cream. Cream of low acidity will remain in good condition for several months if sufficiently low temperatures are employed; i.e., 0°F. or lower. Ice cream of desirable flavor can be made from frozen sweet cream provided not more than one-third of the fat content of the product is derived from this ingredient.

Ice cream mixes containing frozen sweet cream are high in viscosity, due in part to excessive clustering of the fat globules after homogenization. Frozen sweet cream has been found to be an overrun deterrent, such mixes requiring about 10 to 20 per cent more time to whip. An attempt is being made to find a method for storing sweet cream so that it can be used without increasing the mix viscosity and length of freezing. Data secured to date indicate that combining some of the gelatin or sugar with the cream previous to freezing will produce a resultant mix of lower viscosity and a more normal freezing time.

A Study of Electric Refrigerated Milk Cooling Tanks. (J. H. Frandsen and H. G. Lindquist.) Work on this project was started in the summer of 1929, the object being to determine the efficiency and cost of cooling milk in electric refrigerated cooling tanks. Several different makes of electric refrigerated units have been installed and data collected as to the length of time required to cool milk from 90 to 50°F., and the amount of current necessary to cool milk under ordinary farm conditions. The data thus far collected are not sufficient to warrant definite conclusions.

A Study of the Changes that Occur in the Storage of Frozen Sweet Cream. (H. G. Lindquist). Preliminary experiments have been made, but not enough work has been done to justify conclusions.

DEPARTMENT OF ENTOMOLOGY

H. T. Fernald in Charge

Dates of Hatching of Scale Insects and When to Spray for Them. (A. I. Bourne). The necessary observations on critical stages in seasonal development of these insects and their correlation with climatic conditions for the past season have been recorded.

The scarcity of previous work along these lines gives almost no background of accumulated facts to assist in interpretation of results. This has necessitated observations over a long period, to determine accurately the influence of abnormal seasons.

It has been found that the variations in temperature in late fall and the severity of the following winter exert a great influence upon the rate of development of these insects.

The marked contrast in weather conditions in the years 1928 and 1929 has afforded unusual opportunity to determine the effect of such extremes, particularly upon the spring appearance of young scales in the single-brooded species, Oyster-shell Scale, and upon similar development in the summer generation of a two-brooded species, the Pine Leaf Scale.

Investigation of Materials Which Promise Value in Insect Control. (H. T. Fernald and A. I. Bourne). The chief attention this season has been directed toward the comparative efficiency of different types of oil sprays for European red mite control, as well as checking them from the standpoint of safety to the trees.

Against a moderate infestation of red mite, almost all of the oils tested gave satisfactory control, indicating that in general, under such conditions, thoroughness of application and proper timing are more essential than the mere choice of oil spray.

In some cases, after conference with manufacturers, oils were applied at an advanced strength over that previously recommended, in order to meet Massachusetts conditions better.

The effect of combining certain types of oil sprays with sulfur or copper fungicides was studied, both from the standpoint of safety to the trees and of effectiveness against red mite. The results of these tests indicated that these oils can be so used, safely and without impairing their insecticidal value.

The abnormally high temperature in early April afforded opportunity to study the effects of oil sprays for delayed dormant application under conditions very unusual in Massachusetts. The burning which resulted pointed out the posibility of maximum temperature requirements for safe application of oil sprays in addition to the minimum limits with which Massachusetts growers are familiar.

A study of a recently developed sulfonated, oxidized oil spray was begun, particularly as to its possibilities as an activator for nicotine. Preliminary tests have shown that a dilution of one-half to one per cent, when combined with nicotine sulfate, gives satisfactory control of some insects, with concentrations of nicotine much lower than those at present recommended. This means a material reduction in the cost of such sprays which are at present relatively expensive.

Control of Onion Thrips. (A. I. Bourne). The summer of 1929 was characterized by conditions of severe drought. Such an abnormally dry season was very favorable for thrips development. Throughout the early summer the infestation was comparatively light and of little consequence. During July and August, when the effects of the continued drought became more pronounced, thrips increased rapidly and many onion fields suffered severely from the combined effects of thrips and dry weather. In the absence of blast and mildew, however, the plants on the whole remained green and vigorous considerably later than in the years when those diseases were prevalent. The period of abundance and activity of thrips was proportionally lengthened.

Some growers became interested in the possibilities of biological control of thrips, purchased a quantity of lady beetles from a western state, and liberated them in a field where thrips were abundant. The effort was not crowned with any conspicuous success. Examination of onion fields in the Valley, throughout the season, resulted in the collection of at least five different species of predacious beetles, all of them well established in this region. The beetles imported from the West belong to one of these species.

Field tests demonstrated the nicotine-soap combination to be an effective killing agent against thrips, and the machinery for application practicable. In cooperation with the Department of Botany studies were made of the relative efficiency of combined sprays of nicotine and copper fungicides, for the control of thrips and blast or mildew, or both.

Preliminary tests were made of a new spray material designed to serve as an activator of nicotine, with the view of lowering the strength of the nicotine sulfate spray from present requirements without impairing its efficiency against thrips.

In cooperation with the Department of Botany, observations of onion fields in the Valley were made throughout the season to note the appearance and extent of blast and the correlation, if any, of this disorder with insect activities.

Control of the Plum Curculio in Apples. (W. D. Whitcomb, Waltham). High temperatures in May and June stimulated the beetles to make two to three times as many punctures per day as were observed in previous years. Parasitism was exceedingly low. Early in the season the number of punctures made in sprayed and unsprayed fruit was approximately equal, but two weeks later the beetles made 103 punctures in the unsprayed fruit and 12 in the sprayed fruit. Laboratory poison experiments again indicated that lead arsenate at the rate of 2 pounds in 50 gallons of water is the minimum dosage which should be used, and that calcium arsenate is superior to lead arsenate in equal units by weight. Fish oil sticker again increased the effectiveness of the poison but less than in previous years.

In confinement, beetles were attracted to and fed freely on dried fruit baits containing various poisons. However, preliminary trials with these baits in the orchard failed to show beneficial results, indicating that the method of exposing the baits needs further study.

Spray Residue Problem and Its Relation to Orchard Practices. (A. I. Bourne). Spraying and dusting experiments on the three standard varieties of apples, Wealthy, McIntosh, and Baldwin, were continued in 1929.

The experience of the past summer has demonstrated the very great influence which the type of season has upon the problem of spray residue on fruit at harvest. Compared with the two previous years, the rainfall in 1929 during the period between the calyx spray and harvest was relatively insignificant, as noted below.

	Rainfall—inches		
	1927	*1928*	*1929*
Wealthy	13.0	23.5	7.8
McIntosh	14.6	24.6	8.4
Baldwin	18.5	25.0	10.3

Under such conditions, much of the spray deposit normally removed from the fruit by rainfall persisted throughout the season. Consequently, sprays could not be applied after early summer with any assurance of safety, especially on Wealthy or McIntosh. On the other hand, even the late summer applications of sulfur—lead dusts on these same varieties were made without encountering any difficulties as to residue.

Biology and Control of the Carrot Rust Fly. (W. D. Whitcomb, Waltham). The general infestation by the first generation of the carrot rust fly was much less than in 1928 due to unfavorable conditions for oviposition; consequently injury by the second generation was also somewhat lighter.

Flies emerged from 92 per cent of the pupae confined in *slightly* moist sand and loam, and from 80 per cent of those in moist sand and loam, but from only 50 per cent and 33 per cent of those in wet loam and dry sand, respectively. Due to climatic conditions the flies emerged from 10 to 14 days earlier than in 1928. This condition continued through the summer and resulted in the emergence of thirteen third generation adults, the first observed at Waltham.

Preliminary studies were made with potted carrots grown from seed treated with mercury compounds. Where calomel was dusted on the soil as well as the seed, the plants showed 35 per cent less injury than plants from untreated seed. Plants from Semesan treated seed showed very little infestation.

Studies were made of the effect of different sprays on the adult flies. The relation of planting dates to percentage of injury by first generation larvae was also studied as well as relative susceptibility of different varieties.

Mulch paper effectively checked the first generation infestation, but the second generation damage was from 5 to 17 per cent greater under the paper.

Studies were made with insecticides and repellents. Some of the materials showed considerable promise, although the protection from second generation attack was somewhat less pronounced.

Systematic Study of Oil Sprays. (H. T. Fernald). The entomological part of the project during 1928-29 has been restricted mainly to conferences with the Department of Chemistry which is cooperating in the project, in order to keep in touch with the work done and to obtain a thorough understanding of the chemical processes made use of. It now seems probable that some of the materials desired for field tests may be available for this purpose the coming spring, and these tests will be made by the Department of Entomology.

FARM DEPARTMENT

Enos J. Montague in Charge

Intensive Grassland Management under the Hohenheim System. (E. J. Montague, C. H. Parsons and R. C. Foley). In the spring of 1928 an experiment in intensive grassland management, under the Hohenheim System, was put into operation. This originated in Germany during the World War and has since been used successfully in the Netherlands and the British Isles. It is designed to provide a luxuriant growth of grass rich in protein, thereby making it possible for the dairy farmer to produce on his own farm most of the feed necessary for his herd, at least during the summer months. On the College farm this system has greatly reduced the amount of concentrates fed in the summer and has yielded an average return per acre of $69 a year from the plots to which complete fertilizer was applied, as compared with an average return of $22 from the unfertilized plot.

The Hohenheim System is based upon four distinct principles: division of the area into plots, combination of grazing and hay land, use of concentrated fertilizers, and rotational grazing.

About seventy-five acres of land that had formerly been in a crop and pasture rotation were divided and fenced off into nine equal plots. The first six were used exclusively for grazing. As checks, Plot 4 was unfertilized both seasons, and in 1929 Plot 6 received only phosphoric acid and potash. Plots 7, 8, and 9 were cut for hay in early June and then used for reserve pasture during the latter part of the season. In the early spring Nitrophoska II, a high analysis complete fertilizer, was applied. Calurea, a concentrated nitrogenous fertilizer was applied as a summer top-dressing three times during the season. The cattle were divided into groups—high producers, low producers, and dry cows and young stock—and were rotated from plot to plot, the first use of the fresh pastures always being available to the high producers who were followed in turn by the other two groups.

Accurate records were kept of the condition of the cattle, milk produced, additional feed consumed, and cost of all field operations. A daily record was kept for every plot of the number of each class of stock and the amount of milk produced. The day before the cows were turned onto a plot, grass samples were taken and analyzed for protein content by the Department of Chemistry. These were found to average 17.5 per cent crude protein in dry matter on the fertilized plots, as compared with 12.2 per cent on the plot which received no nitrogen.

Both pasture seasons have been abnormal; the first extremely wet and the second very dry. From the results obtained it is expected that a normal season will show much greater possibilities for the system; therefore, it is planned to continue the experiment.

The results so far seem to warrant the following conclusions:

1. A heavy, thick turf is essential for the best results from fertilizer application.
2. The application of fertilizer increases the quality and quantity of pasture grass.
3. Nitrogenous fertilizers are necessary for the greatest return, when a good pasture turf is established.
4. Proper management of the herd and plots, combined with fertilizer treatment, is essential for the greatest net returns from an intensive grassland system.

DEPARTMENT OF FARM MANAGEMENT

J. A. Foord in Charge

Enterprise Relationships and Farm Organizations on Selected Dairy Farms in Western Massachusetts. (R. L. Mighell). This project, begun in the latter part of 1928, has been continued throughout the year and quite complete records of the year's work on 19 selected dairy farms in the western part of the state have been obtained. Records of labor and its distribution, as well as of the financial and material income and outgo, have been secured and should yield valuable data when tabulations and comparisons are made.

The Place of Poultry Production on Massachusetts Farms. (R. L. Mighell and F. H. Branch). Work on this project was completed and the results published as Bulletin No. 251. (See list of publications).

Types of Farming in Massachusetts 1840-1925. (Marian Brown). This project was planned as a historical study to form a basis for future work. Most of the material and data had been collected at the time of Miss Brown's resignation in October, and will be prepared for publication by another member of the department.

Factors Responsible for Variations in Production and Cost of Milk in Massachusetts. (R. L. Mighell). Some progress has been made in reviewing the literature and accumulating data on this project, but more work must be done before definite conclusions can be reached.

Other Activities. The Department has cooperated with the State Department of Agriculture and the Massachusetts Industrial Commission in a business survey of Connecticut Valley farms, the planning and supervision of the field work being entirely cared for by this department. Records of approximately 350 farms, mostly those producing onions and tobacco, have been secured, and a careful tabulation and study are being made of the data.

FEED CONTROL SERVICE

Philip H. Smith in Charge

The Feed Control Service comprises not only feed inspection, but several other activities, as listed below:

Feed Control (General Laws, 1920, Chapter 94)
Seed Control (General Laws, 1927, Chapter 94)
Dairy Law (General Laws, 1920, Chapter 94)
Advanced Registry Testing
Miscellaneous Work

Feed Control. (P. H. Smith, H. R. DeRose, J. W. Kuzmeski, M. W. Goodwin[1], J. B. Zielinski, Jr., F. A. MacLaughlin). During the fiscal year, 1640 samples of feeding stuffs officially collected were examined in the control laboratories. The results indicate that guarantees placed upon these products are with few exceptions reliable, and that such lapses as occur are not serious. The retail feed business is gradually being absorbed by chain systems, which may in time seriously affect the revenue accruing to the State through the reduction of the number of brands of feeding stuffs sold. During the past year the gross receipts from this source were $19,800 derived from 990 registrations at $20 a brand. Of this sum, $11,000 is appropriated to the Experiment Station for the purpose of feed control.

Seed Control. (P. H. Smith, O. W. Kelly, C. L. Beane[2]). The seed laboratory has been established at the Experiment Station primarily for the purpose of inspecting seed samples collected by the State Commissioner of Agriculture, who is designated under the act as administrative officer.

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[1] Resigned October 1, 1929.

[2] Resigned November 1, 1929, to accept the position of chief clerk in the Department of Botany.

The work accomplished during the two years that the law has been in operation indicates that, on account of the general good quality of seed offered, the laboratory can consistently devote less time to seed inspection and rather more time to research problems pertaining to seed.

Summary of Samples Analyzed. 1929

	Non-Official	Official	Total
Purity analysis only	27	55	82
Germination test only	228	181	409
Both purity and germination test required	131	249	380
Totals	**386**	**485**	**871**

In cooperation with the Department of Vegetable Gardening, 93 samples of onion seed were examined: and 31 samples of alfalfa and clover seed were submitted to the Department of Agronomy for field tests in order to determine trueness to type.

Dairy Law. (P. H. Smith, J. T. Howard, H. L. Allen). The work under this law involves:

1. The testing of Babcock glassware for accuracy.
2. The examination and award of certificates of proficiency in the use of the Babcock test.
3. The annual inspection of creameries, milk depots, and board of health laboratories where the test is used as a basis for fixing the value of milk and cream.
4. An amendment to the Dairy Law enacted at the 1929 session of the General Court authorizes the adoption of Rules and Regulations in order to promote uniformity and accuracy in testing. These rules and regulations have been published and distributed to operators. This amendment also makes possible investigation in order to determine if these rules and regulations are followed.

During the year ending December 1, 1929, 8515 pieces of Babcock glassware were tested. Condemned bottles amounted to less than one per cent of the total tested. Eighty-nine certificates of proficiency were awarded. One hundred and fifty-three creameries, milk depots and milk inspectors' laboratories were visited in order to check methods and pass upon equipment in use. As a result of this inspection, major repairs were ordered on 12 machines, minor repairs on 30, and 2 machines were condemned outright. Sealed glassware was ordered at four places, and cream scales at the same number.

Advanced Registry Testing. (P. H. Smith). At the present time the work of Advanced Registry Testing is cared for by the services of one clerk and seven supervisors. The volume of work does not change materially from year to year. In November, 1929, there were on test 568 cows, located on 78 different farms. Many of the pure bred cattle clubs are now giving recognition to Herd Tests in addition to the testing as it has been practiced in the past where individual animals of expected high production were selected for record work. The Herd Test is an incentive to breeders to maintain a high average production in their herds, with the consequent weeding out of inferior animals.

Miscellaneous work. (P. H. Smith, H. R. DeRose, J. W. Kuzmeski, J. B.

Zielinski, Jr.). Numerous analyses are made for residents of the State and other departments of the College. Analyses requested must be comparable to the general routine work of this department.

Summary of Miscellaneous Work, 1929

Materials sent in:	
Milk and cream, butter fat only	502
Milk, solids and fat	75
Feeds	97
Pasture grass, dry matter	562
Pasture grass, fodder analyses	45
Pasture grass, nitrogen	47
For other departments of Experiment Station and College:	
Milk for butter fat	127
Moisture tests, forage crops	706
Complete fodder analyses	192
Moisture tests and nitrogen	158
Chicken bones	2

FERTILIZER CONTROL SERVICE

H. D. Haskins in Charge

Fertilizer Inspection. (H. D. Haskins, H. R. DeRose, M. W. Goodwin, J. W. Kuzmeski, J. B, Zielinski, Jr.). During the season of 1929, 104 firms or individuals have registered in Massachusetts 638 brands of fertilizer, unmixed fertilizing materials and agricultural lime. The following table shows the nature of these materials as well as statistics with reference to their inspection.

Products	Brands Registered	Brands Collected	Samples Collected	Number of Analyses	Number of Determinations
Mixed fertilizers	365	347	1131	536	7341
Ground bone, tankage and fish	66	61	144	81	419
Nitrogen products, organic and mineral	78	69	229	143	440
Phosphoric acid products	33	30	102	42	231
Potash products	32	30	68	38	115
Dried pulverized natural manures	17	16	69	16	110
Miscellaneous materials	16	15	29	22	163
Lime products	31	30	62	35	267
Totals	638	598	1834	913	9086

In securing representative samples for the year's inspection, the four agents sampled 22,257 sacks or containers, representing 8285 tons of material; about 266 towns and 1005 agents were visited.

From July 1, 1928 to July 1, 1929 the following tonnages of fertilizer and plant food were sold in Massachusetts:

Fertilizer and Plant Food Tonnage

	Fertilizer	Plant Food Elements Nitrogen	Plant Food Elements Available Phosphoric Acid	Plant Food Elements Potash
	Tons	*Tons*	*Tons*	*Tons*
Mixed fertilizers	41,529	1730	3206	2549
Unmixed fertilizer chemicals and materials	18,788	1115	1737	596
Pulverized natural manures	2,174	51	32	68
Totals	62,491	2896	4975	3213

Full details of the fertilizer and lime inspection work may be found in Bulletins 51 and 52, Control Series.

Miscellaneous Analytical Work. (H. D. Haskins, H. R. DeRose, M. W. Goodwin, J. W. Kuzmeski). Between November 1, 1928 and April 1, 1929, the activities of the department included cooperative chemical work with other departments of the institution. The general nature and extent of this work is shown by the following summary:

Soil, complete mineral analysis	20
Corn plants, complete ash analysis	9
Alfalfa, partial ash analysis	6
Timothy, partial ash analysis	4
Tobacco leaf, complete ash analysis	4
Tobacco leaf, dry matter and partial ash analysis	59
Tobacco stalks, dry matter and partial ash analysis	67
Soil, for carbon, nitrogen, carbonic acid, organic and volatile matter	26
Processed organic ammoniates, complete analysis including nitrogen activity tests	24
Manure, complete fertilizer analysis	4
Insecticides	2
Millet seed and straw, dry matter and nitrogen	96
Gladiolus bulbs, ash analysis	1
Ground seeds of plants, ash analysis	4

The department has also made the following analyses for farm organizations, institutional departments, and private individuals. For this latter service a nominal charge is made.

Fertilizers	21
Peat and pond deposits	22
Lime products	5
Pulverized manures	4
Cotton waste products	4
Mulch	3
Soils for partial analysis	23
Wool waste	2
Boiler sludge	2

In addition to the above, the department has cooperated as usual with the Association of Official Agricultural Chemists.

Vegetation Pot Experiments. (H. D. Haskins, A. B. Beaumont, G. J. Larsinos). This experiment, comprising 96 pots, was conducted in further study of the nitrogen availability of processed low grade organic substances high in nitrogen which are used in mixed commercial fertilizers. Also, pots were included to note the effect of the use of varying amounts of manganese sulfate. Results of both experiments are reported in Control Bulletin 51.

DEPARTMENT OF HOME ECONOMICS RESEARCH

Esther Davies in Charge

Present Practices of Massachusetts Elementary Schools with Regard to School Feeding and Transportation and Their Effects upon Health of Pupils. (E. Davies and C. B. Church.). The field work for this project has been completed, most of the data tabulated, and a report of the findings with regard to food service has been prepared. The 222 towns of less than 5,000 population included in the study have a total elementary school enrollment of 57,600 pupils, 15,000 of whom must be furnished transportation to and from school. These towns have 800 school buildings: 370 one-room, 208 with two or three rooms, and 222 with four or more rooms. In 71 per cent of the buildings there is no food service of any sort at any time in the entire school year, and only one-fourth of the others have anything more than a haphazard service during the winter months. In general, the decision with regard to food service rests entirely with the individual teacher, and there is neither encouragement nor appreciation of her efforts on the part of the school administration.

Detailed records as to the cause and the duration of absences from school were kept by the teachers of 16 schools scattered throughout the State. The average number of days attended is greater for the children who walk to school than for those transported. The incidence of absence due to illness is the same for the two groups, but the illness absences of the transported group are of longer duration. The greatest difference between the two groups is in the amount of time absent from school in order to work at home. The transported group, either because of distance from the truant officer or because there are more tasks which can be delegated to the farm child, has three times as high a percentage of absence due to labor at home as has the group who walk to school.

The report gives an analysis of the situation now existing with regard to school feeding and transportation, and recommendations of improvements which might be made without appreciable added financial burden on the rural towns.

The Comparative Values of Milk and Tomato as Supplementary Feeding in a Rural Elementary School. (E. Davies and C. B. Church). This project was undertaken to determine to what extent the nutritional status of the elementary school child can be improved by school feeding, and whether—given the usual home diet of rural Massachusetts—milk or a vitamin C rich food is the better for the purpose. Work was begun in September, 1929, in the schools of a typical rural town, and the experimental feeding is to be continued for two school years. No conclusions can be reached before the end of the experimental period.

DEPARTMENT OF HORTICULTURAL MANUFACTURES

W. W. Chenoweth in Charge

The Extraction of Fruit Juices by Heat. (C. R. Fellers). This project has been continued, using small fruits including raspberries, blackberries (wild and cultivated), blueberries, currants, plums and grapes. With the experimental data complete, the results of the two-year study on small fruits will soon be presented as a bulletin.

The use of pectin in fruit jellies has been studied, and work has been done on a method for home extraction of pectin from cull apples or thinnings. In cooperation with the Department of Dairy Industry, the substitution of pectin for gelatin as an ice cream stabilizer was found to decrease overrun.

The use of frozen apples for cider making was found to be satisfactory, the expressed juice being very heavy and rich in pectin. This juice with added sugar gives an excellent cider jelly.

Manufacture and Preservation of Cranberry Products. (C. R. Fellers and F. P. Griffiths, W. W. Chenoweth). Several barrels of cranberries were canned in various types of tin cans and glass jars and some stored for a year at 90° F., 70° and 45°. The effect of cold storage upon the quality of canned cranberry sauce was very marked, the discoloration and abnormal flavor being very much reduced. A good cranberry sauce was found to jell at 216-218° F., contained approximately 43 per cent sugar, and showed a bloom jelly strength of about 150 grams. Close cooperation with the several cranberry packers and the State Cranberry Station at East Wareham has been maintained in this project.

The development of a cranberry syrup was attempted. It was found impossible to eliminate a very troublesome pectinous precipitate from the syrup. The condition was remedied somewhat by using a very short extraction period and expressing the juice before all of the pectin had been liberated.

Candied cranberries were made in the laboratory and seem to be in many ways superior to the commonly used candied cherries.

Utilization of Onions by Canning. (C. R. Fellers). Further progress has been made, particularly in methods of preparation of onions for canning. A short blanching (1.5—3 min.) in boiling water loosens the outside skin and greatly facilitates its removal. The use of zinc enamel-lined tin cans to prevent a black or smut formation has again proved very efficacious. The onion contains much loosely combined sulfur which is liberated during the canning process and combines with metals of the container to form sulfides. Since zinc sulfide is white, there is little objection to it.

Work on onion pickling and drying has been continued. Several pounds of onion powder for flavoring foods was prepared. It is believed this product has good commercial possibilities.

The Nitrogen Distribution of the Edible Portion of the Onion. (F. P. Griffiths). The total nitrogen and various amino acid fractions were estimated. The Van Slyke separation method was used.

Utilization of frozen fruits in ice cream. This joint project carried on in the departments of Dairy Industry and Horticultural Manufactures is now in its second year. Two fruit crops consisting of strawberries, raspberries, blackberries, cherries, and peaches have been cold packed with various ratios of cane and corn sugars, stored at 15°F., and used in fruit ice cream mixes. The most satisfactory varieties of strawberries were Howard 25, Howard 17, Bliss, King Edward, Beacon, First Quality and Marshall, while Herbert, Cuthbert and St. Regis varieties of raspberries were very suitable for cold packing. The optimum fruit to sugar ratio was 2 to 1 and 3 to 1 for strawberries and cherries and 3 to 1 for raspberries and peaches. Corn sugar discolored the fruit and was unsatisfactory. Fruits frozen without sugar lost, to a considerable degree, their characteristic fresh flavor and color. Prompt freezing at 0°F. followed by cold storage at 15°F. or less kept the fruit in good condition for over a year. Such frozen fruit was comparable to fresh fruit for use in ice cream, jams, jellies, and juices.

Pasteurization of Dried Fruit. (C. R. Fellers and J. A. Clague). Research has been conducted on the heat treatment of dried fruits, particularly dates and figs, with the view of developing an effective pasteurizing procedure for these products. A preliminary report on this work is now in press (*American Journal of Public Health*). A heat treatment of 180° F. for 60 minutes at 75 per cent humidity will effectively destroy *Escherichia coli* in packaged dates and actually improves the quality, texture, and color of the fruit.

Non-Project Research. (C. R. Fellers). The canning of citrus juices, the fermentation and preservation of citron, and a preliminary study of cider preservation with benzoates have been carried on.

DEPARTMENT OF LANDSCAPE GARDENING

Frank A. Waugh in Charge

Lawns and Lawn Grasses and Lawn Management. (L. S. Dickinson). As the summer of 1929 was unusually dry, important observations have been made concerning the advisability of fertilizing turf during a hot dry season. Excellent turf of each of the basic grasses—bent, Kentucky blue grass, and fescue—has been maintained by monthly applications of castor bean pomace or cottonseed meal. Check plots receiving no fertilizer were severely dried, thus permitting an invasion of weed growth.

Additional field studies have been made of the fungus causing snow mould, and laboratory experiments have been conducted during the summer concerning the large brown patch disease (*Rhizoctonia solani*). These experiments verified the field observations, and it now appears that an attack of this disease can be accurately forecast.

Seven species of grasses imported from Germany are being tried as fairway grasses, and there have been many strains of bent added to the trial plots. Also, several strains of bent have been discarded, as they did not appear to be adapted to putting conditions.

The series of plots established in the fall of 1928 in cooperation with the United States Golf Association wintered very well, and while only one year old they are furnishing many data. In this series the annual blue grass and European red fescue plots were much affected by the hot dry season.

Approximately one acre more land has been assigned to turf culture studies. This will be used for variety plots, turf nursery, and student plots.

DEPARTMENT OF PLANT AND ANIMAL CHEMISTRY

J. B. Lindsey in Charge

The Efficiency of Copper Fungicides. (E. B. Holland and others). A summary of the laboratory work relative to the preparation of low and high basic copper sulfates and of the composition and physical characteristics of the laboratory and manufacturers' samples has been presented in Bulletin 254 together with the results of several year's field tests of their efficiency as fungicides, both as sprays and dusts, in the control of diseases on cucumbers, celery, potatoes and fruits. The project is held in abeyance awaiting further developments of the subject.

Supplements for Copper Fungicides. (E. B. Holland and others). Data from many experiments made at this Station, both in the laboratory and in the field, pertaining to the use of supplements for incorporation into different copper fungicides intended to remedy some real or fancied defect have been published in Bulletin 252, to which the reader is referred for full information.

The Effect of Fertilizer and Cultural Treatment on the Nitrogenous Compounds of Havana Seed Leaf. (P. R. Nelson). The work on tobacco originally undertaken by E. B. Holland and continued by P. R. Nelson endeavored to measure the effect of varying amounts of nitrogen, high and low topping, and different stages of maturity on the nitrogen compounds of "seconds" grown on the experiment plots during the season of 1928. This is a sub-project of the Department of Agronomy and is further reported by that department.

Oil Sprays. (E. B. Holland). A study of oil sprays has been undertaken with the view of determining the relative composition of the different brands of stock emulsion and miscibles that have been employed by the Department of Entomology. An effort is being made to produce similar products of definite composition for field tests. Definite results are not yet available for publication.

Nitrogen Fixation in the Presence of or as a Result of the Growth of Legumes versus Non-Legumes Under Certain Defined Agronomic Conditions. (F. W. Morse). The crops produced this year (1929) were red clover for a legume and timothy for a non-legume. They were the second year's product from the seeding in the spring of 1928 described in last year's report. Both lots wintered well. Conditions were favorable for growth until early in June, after which there was little rainfall. The crops were cut, sampled and weighed on July 1 and 2. They were a repetition of those produced in 1924, therefore a comparison of results for the two seasons is of interest. The comparison is made between the products of the areas that have not received nitrogen in fertilizers since 1882.

Dry Matter and Nitrogen Removed from the Plots
(*Kilograms per Acre*)

	Dry matter		Nitrogen	
	1924	*1929*	*1924*	*1929*
Clover, Plot 7	1552	1712	43.2	41.2
Clover, Plot 9	1868	1838	49.9	41.9
Grass Plot 7	408	508	3.4	4.9
Grass Plot 9	496	623	4.5	6.1

The particularly interesting result is that after an interval of five years of continuous cropping and removal of nitrogen, the soil which has not grown a leguminous crop in that period held its own and something more, measured by both dry matter and nitrogen in the crops removed this year.

Chemical Changes in the Cranberry During Ripening and After Harvesting. (F. W. Morse). The work during the past year has been principally the analysis of numerous varieties of cranberries and samples from different bogs. Numerous specimens of the 1929 crop have been received from New Jersey and Wisconsin cranberry growers, as well as from the Cape Cod region. At this time it is possible to report nothing more than the range of percentages found by the determination of total acid, total sugar and dry matter in the varieties so far examined.

Ten varieties of the crop of 1928 were received from Cape Cod growers in November of that year. During October and November of this year, there have been analyzed 41 varieties of the crop of 1929 which were representative of all three states—Massachusetts, New Jersey and Wisconsin. The results expressed as minima and maxima so far observed are as follows:

	Dry Matter %	Total Sugar %	Total Acid %
1928 10 varieties	11.3-13.1	3.45-5.22	2.14-2.79
1929 41 varieties	11.2-13.5	2.50-5.45	2.07-2.71

The much wider range in percentages of sugar in 1929 was probably due to a wide variation in the maturity of the fruit when harvested. The study of cranberries during ripening has shown that sugar is rapidly increased during the last week on the vines, accompanied by a noticeable development of color of the berries. Several samples of this year's crop were very light colored, and the lowest percentages of sugar were found among them.

Record of the Station Herd. (J. B. Lindsey and J. G. Archibald). This project has been carried on over a long period of years incidental to other work. The records for 1928 show that twelve cows (ten grade Holsteins, one grade Jersey, and one pure bred Jersey) completed a normal lactation period during the year. The average production was 9045 pounds of milk testing 12.27 per cent solids and 3.8 per cent fat, with a feed cost per cow of $164.97, or 4.01 cents per quart of milk. Feed cost was based on hay at $20, silage at $8, green feed at $8 a ton, and grain at market price. Under conditions prevailing it was not practicable to determine the overhead.

In 1929 the herd included 20 cows milked during the year. A number, however, had only short lactation periods, varying from a few days to six months. The records of ten cows having normal lactation periods are as follows: Average yearly production 8534 pounds, testing 12.40 per cent total solids and 3.97 per cent fat, with a feed cost of $143.63 per cow, and 3.70 cents per quart of milk. The feed cost of roughage was figured on the same basis as for 1928, with grain at prevailing market prices. The feed cost of milk was a little less in 1929 than in 1928 due, in a measure, to the increased use of roughage and less grain.

Milk Substitutes in the Growing of Young Calves. (J. B. Lindsey and J. G. Archibald). Results of work on this project over a period of several years have recently been published in Bulletin No. 253. The method which has been the most satisfactory compromise between economy and good growth has involved the use of skim milk powder in limited amount (about 125 pounds per calf) up to four months of age.

The project is being continued with the idea in mind of developing a system based largely on dry feeding after the first few weeks, little or no liquid except water being fed.

Mineral Supplements for Dairy Cattle. (J. B. Lindsey and J. G. Archibald). The final report of six years' investigation of this subject has recently been published in Bulletin No. 255. Little, if any, benefit was noted from the feeding of bone meal. Some slight benefit was noted from feeding dicalcium phosphate (precipitated bone), but not sufficient to warrant recommendation of its general use. Average producing cows (5000-8000 lbs. yearly) fed on good quality roughage with the amounts of grain ordinarily fed in New England seem to obtain sufficient mineral matter from their ordinary feed. Heavy producers may benefit from the addition of mineral supplements, but the efficacy of the practice is by no means well established.

Mineral Constituents of Forage Crops. (J. B. Lindsey and J. G. Archibald). Results of this project form a part of the above-mentioned Bulletin No. 255. No pronounced deficit of mineral constituents has been noted in the Massachusetts roughages examined in the course of this work. The calcium content of the hays analyzed is worthy of note, it being somewhat higher than the values given by other authorities.

Mineral Requirements for the Growth of Dairy Heifers. (J. B. Lindsey and J. G. Archibald). Work on this project, organized about three years ago, is being actively pursued. At date of writing (December, 1929) eight heifers have been carried through two years of intensive experimental trials, four on a ration high in calcium, and four on a ration low in that element. An accurate check has been kept on the intake and excretion of calcium and phosphorus by these animals, and careful growth records have been kept. The work has not yet reached a stage where definite conclusions are warranted. Of necessity it must be a long-time project.

A Comparison of Two Systems of Dairy Cattle Feeding—High Roughage and Low Grain vs. Low Roughage and High Grain. (J. B. Lindsey and J. G. Archibald). This project was organized a year ago in order to obtain some definite experimental evidence on a problem which is much discussed by practical feeders and on which various recommendations have been made from time to time, but without a definitely established basis of fact.

The Station herd has been divided into two groups, one receiving grain at the rate of one pound to four and one-half pounds of milk, 40 pounds of silage and what hay they will clean up; the other group receiving grain at the rate of one pound to two and one-half pounds of milk, 25 pounds of silage and what hay they will clean up. The cows are being carefully observed, and the usual checks on live weight each month, milk production, and the reproductive function, are being maintained. It is too soon to draw definite conclusions from the trial. The plan is to continue it for at least three lactation periods of all the cows.

The Chemical Composition of Grass from Plots Fertilized and Grazed Intensively. (J. G. Archibald). The department has cooperated during the past two years in a study of an intensive system of grassland management being carried out on the College farm. A study has been made of the chemical composition of grass as affected by the intensive fertilizer treatment and grazing which the system involves. Results for 1928 have been published in the *Journal of the American Society of Agronomy* for June 1929. The study for 1929 has not yet been completed. Briefly: the fertilizer treatment increased the percentage of nitrogen, phosphorus, and ether extract, and decreased slightly the percentage of crude fibre and calcium, in the dry matter of the grass. Acre production of all constituents was increased, nitrogen being nearly doubled, while phosphorus and ether extract were increased by about one-half.

A study of the seasonal variations in composition showed that grass kept in the vegetative stage by grazing may be quite different in chemical composition in midsummer from what it was in the spring. The seasonal factors, rainfall, temperature and sunshine, exert their influence irrespective of the stage of growth of the plant.

Utilization of Onions by Canning. (C. P. Jones). The object of the studies on the chemistry of the onion has been to ascertain (1) its mineral and proximate food constituents, (2) the cause of its discoloring action upon the tin in which it is processed, and (3) the reason for the darkening of the onion itself in the canning process. Many of the inorganic and organic constituents of the onion have been already determined. Further additions relative to both are to be made.

Discoloration of Can. Preliminary studies made on the discoloration of plain tin cans by commercially processed fruits, vegetables, flesh products and soups, and by laboratory canned materials indicated that sulfur from the protein molecule caused the discoloration. Experiments conducted with cysteine hydrochloride further confirmed this view. In the case of the onion, other sulfur compounds are present in addition to those associated with the protein molecule, and were therefore considered as possible discoloring factors.

Unfortunately, lack of laboratory facilities prevented the extraction, recovery and consequent identification of the sulfur oils contained in the onion. However, several analogous oils (technical alkyl sulfide and disulfide, allyl sulfide, and mustard oil) were investigated as to the probability of such sulfur compounds constituting discoloring agents. This was found not to be the case, with the exception of mustard oil. The presence of mustard oil would result, through decomposition, in the discoloration of the can to some degree.

Tests indicated that the metallic film formed on the sides of the can was a sulfide of tin rather than of iron.

Black deposits occurring on the head space end of some enameled cans were removed and tested for their metallic constituents. Both iron and zinc were found present. Zinc oxide is a constituent of the enamel coating. The amount of iron obtained indicated other forms besides the sulfide, presumably oxides.

Discoloration of the Onion. In all cases canned onions were found to be normal both in firmness and color when removed from the can, while the onion liquor was of a pale green color. Exposure to the air or to the influence of oxidizing agents resulted in the development of a dark olive green color of tissue and to a dark green to brown coloration of the liquor, regardless of whether the product was processed in plain tin or enameled cans. Onions processed in glass, on the other hand, when exposed to the same oxidizing conditions, discolored slowly, changing in color to a light brown only upon long standing. This pronounced difference in color between onions processed in glass and those canned in tin was believed to be due to the influence of soluble iron.

Examination of the liquor from both the plain and enameled cans proved the presence of considerable ferrous iron in solution. Much more iron was recovered from the liquor of the plain can than from the enameled can.

A flavonol pigment, probably quercetin, was proved to be present in the onion bulb. It was found distributed throughout the fleshy inner tissues as well as in the dried outer scales. Experiments carried out with commercial quercetin showed that ferrous ions failed to produce any colored compound, whereas ferric ions resulted in the formation of an olive green to reddish brown ferric compound and also reddish brown solutions depending upon the proportion of iron to pigment.

These investigations indicate that the discolored film produced upon the sides of the plain can in the processing of the onion is due to the formation of sulfide of tin, the source of the sulfur being the sulfur compounds of specific proteins; while the black deposit occurring on the head space end of some enameled cans was largely iron, part as a sulfide and part as oxide. The discoloration of the onion itself is due probably to the presence of iron and quercetin or a similar pigment in solution. The development of the discoloration is believed to involve the following steps: First, metallic iron from the can is rendered soluble by the action of oxygen contained within the head space of the can and also by the solvent influence of the acids and salts of the onion; secondly, the ferrous iron thus formed reacts with the pigment forming the ferrous compound of the pigment; and finally, this ferrous iron, when exposed to the atmosphere, oxidizes and forms an olive green ferric derivative of flavonol.

DEPARTMENT OF POMOLOGY

F. C. Sears in Charge

The Interrelation of Stock and Scion in Apples. (J. K. Shaw and J. S. Bailey). The usual records of growth, bloom, and yield of the trees in the eleven-acre orchard have been taken during the year. The trees have responded to increased applications of nitrate of soda with better growth, and the 1930 crop should be somewhat greater than the rather small crops of previous years. The grass has been suppressed over a space about five feet in diameter around the tree trunks in an effort to prevent girdling by mice. No such injury has appeared since this practice has been followed. Inasmuch as the lease of this land expires in two years, it is probable that the report on this project will be held until the expiration of the lease. No new tendencies have appeared in the past year.

The orchard set in 1928 consisting of McIntosh and Wealthy trees on Clonal stocks from the East Malling, England, Experiment Station, have made a good growth, it being necessary to replace only two trees. It will, of course, be several years before any report can be made of the comparative value of these stocks for the two varieties used. It seems as though there may be possibilities for commercial orchards on these stocks which may be expected to produce semi-dwarf trees which will come in bearing early, thus reducing the capital investment in an orchard at the start of production.

Root cuttings from several of these stocks were set in the spring of 1928 and were large enough to bud the second season. In order to make this method of propagation practical, it must be shown that they have considerably greater value than seedling stocks. Probably the more usual method of mound layering is preferable. It is planned to dig the several hundred of these stocks now in the nursery rows in the spring of 1930, increasing them so far as possible and establishing a new nursery for layering these stocks.

Tree Character of Fruit Varieties. (J. K. Shaw and A. P. French). A study of varietal characteristics of nursery trees continued the past summer, largely in connection with the work of the leaders of this project in certifying varieties for the Massachusetts Fruit Growers' Association. More than two million trees were examined. Substantial progress has been made in determining characteristics for the identification of sweet cherry varieties, and it is now thought possible to detect mixtures of cherry varieties with a fair degree of certainty. This should be valuable, as cherry varieties have been badly mixed in the nursery. Little work has been done with pear and plum varieties for there is at present little demand for these fruits. There are few serious difficulties in variety identification. The problem of peach variety continues troublesome, and yet there is enough known to detect many mixtures and misnamed trees.

A variety nursery was established in the spring of 1929, and grafts and buds of more than one hundred varieties of apples are included. These include all the varieties of apples that are extensively grown in American nurseries, also many new varieties that may have a place in the near future. A few varieties of peaches were also included. It is planned to make a critical study of these varieties as one-year trees in 1930 and as two-year trees in 1931. The photographic method will be used, and it is felt that real progress can be made in recording various differences so they may be understood by anyone familiar with nursery trees.

The Genetic Composition of Peaches. (J. S. Bailey). The orchard of about 1200 selfed and cross-fertilized seedlings planted in the spring of 1928 made satisfactory growth during the past season, and only a very few trees died. Few studies were made the past season, but with the trees in good growth it is expected that studies will be made the coming summer. Some additional work in crossing varieties was done the past summer, but for some unknown reason very few fruits were secured.

The freezing apparatus designed for use in the study of fruit bud hardiness in connection with this project has been completed and considerable data have already been accumulated bearing on the killing point of buds of different varieties and on the effect of various conditions on the killing point. This work is slow and painstaking, and considerable time will be required before sufficient data can be accumulated to warrant definite conclusions.

Testing Methods of Pruning. (J. K. Shaw). This project has been continued the past year, but no attempt to summarize the results has yet been made. No obvious differences have appeared in the quality and quantity of the fruit borne on the heavy pruned, light pruned, and unpruned trees.

Effect of Pruning on Bearing Apple Trees. (F. C. Sears and J. K. Shaw). The past season was the third year of this experiment on old bearing trees. There seems to be a slight though not very consistent increase in size of fruit on the heavy pruned trees. The fruit from these trees is graded according to the State Grading Law each year, and notes of size, color development, and various insects and diseases have been made. No striking differences have appeared; yet the data must be carefully examined before safe conclusions can be drawn.

Comparison of Cultivation and Sod in a Bearing Orchard. (J. K. Shaw). The experimental program as modified in 1927 has been continued. Where nitrate of soda has been used on trees in cultivation without fertilizer, there was distinct increase in yield. Whether a midsummer application of nitrate of soda has increased yield is yet uncertain. The same may be said relative to the sod plot which has for the past three years received potash in addition to nitrogen.

The fertilizer test in the orchard formerly devoted to the study of head formation has continued as for the past four years. No careful study of data has been made, but it seems clear that the nitrogen has improved the trees, although perhaps the unfertilized plots show better performance than one would expect from trees on rather poor soil which has been without fertilizers since the planting of the trees in 1916.

Comparison of Clover Sod and Grass in Sod Mulch Orchard. (J. K. Shaw). This project is a comparison of a complete fertilizer with phosphorus, potash and lime designed to bring in a sod of white clover which may be expected to furnish nitrogen for the trees. The white clover appeared first in 1927 and has been slowly spreading, as the fertilizer treatment has been continued. The trees with complete fertilizer continue to yield more heavily, but it will be interesting to see what happens if the white clover spreads over the entire area of the plot.

Test of Different Amounts of Nitrate of Soda. (J. K. Shaw,). This test on thirty-year-old Baldwins in sod has continued as in the past. No injury to the trees has yet resulted from the use of twenty-five pounds of nitrate of soda per tree. Owing to the small number of trees involved in this experiment, a considerable number of years will be required before it is safe to draw any conclusions.

Comparison of Cultivation and Heavy Mulching for Apples and Pears. (J. K. Shaw). This experiment has been continued as in previous years. The mulched trees continue to yield heavier crops and no injurious effects of the large amount of nitrates in the soil under the mulch have been observed. There seems to be a heavier drop from the trees on the mulch plot just before harvesting, but this is not very serious as the apples are little damaged and may be sold for good prices. It is felt that the system of mulching trees with enough hay or straw to suppress the growth of grass around the trees has possibilities in Massachusetts orcharding.

The Effects of Fertilizer Limitation on Fruit Plants. (J. K. Shaw). This project has been continued as in previous years and nothing new has appeared during the past season. Owing to the fact that the trees, now seven years old, must have sent their roots beyond the boundaries of the plots which are only ten feet wide, it is planned to remove these trees and reset the area with other trees on uniform roots. While the differences between plots have been marked, there are also very great differences between individual trees on the same plot.

Role of Potash and Lime in Fruit Tree Nutrition. (J. K. Shaw). The study of the soils on the orchards referred to in the previous paragraph by means of experiments carried out in Wagner pots, has been continued. Soil from the field plots was placed in the pots after various fertilizer chemicals had been mixed in the soil. The general question of whether the beneficial effects of potash and lime observed in the field were genuine has again been answered in the affirmative, although not quite as emphatically as last year.

Addition of nitrate of soda to soil from the potash plots failed to increase growth as much as lime; therefore, it seems that the increase of soil nitrates in plots receiving lime cannot be the sole cause of improved growth. It is planned to continue this study next year.

Effect of Potash and Lime on Apple Trees. (J. K. Shaw). This project is carried out in an orchard planted in 1915 and involves comparisons of nitrate of soda, potash, superphosphate, and lime, alone and in various combinations. Certain plots are fertilized so as to establish a sod of white clover. This has been successful in many cases and seems to have been beneficial to the trees. Still the trees receiving nitrogen have yielded better than those without, although the difference is not great. No superiority of color of apples from plots receiving complete fertilizer over those from plots receiving nitrogen alone has been observed. In general there is a tendency for plots receiving nitrogen to be inferior in color to those receiving no nitrogen from fertilizers. Observation in this orchard must be continued for several years longer before final conclusions can be drawn.

Study of Varieties of Tree Fruits. (J. K. Shaw and O. C. Roberts). The observations on many varieties of tree fruits growing in the College orchards, which have been carried on for several years, were continued this year. With the accumulation of a considerable number of years' records, it should be possible to make some deductions as to the relation of climatic conditions to bloom and yield.

Fruit Bud Formation in the Strawberry. (R. A. Van Meter). This project was started in the spring of 1928 to study the effect of soil nitrates on fruit bud formation and on fruit production. Forty-five plots of thirty plants each were established in 1928, involving nine fertilizer treatments replicated five times, as given in the last annual report. No differences were observed in the appearance of plants on the different plots either during the summer of 1928 or in the spring of 1929 prior to fruiting. The summer of 1928 was moist and all plots grew well.

At harvest time the fruit from each plant was checked and graded for size. Differences between treatments were slight, but there seemed to be a consistent difference in favor of the later applications.

A new series of forty-five plots of sixty plants each was established in the spring of 1929. These are in nine series, treated as follows:

1. No nitrates
2. August 5, nitrate of soda
3. August 16, nitrate of soda
4. August 16, sulfate of ammonia
5. September 3, nitrate of soda
6. September 16, nitrate of soda
7. September 16, sulfate of ammonia
8. October 4, nitrate of soda
9. October 22, nitrate of soda

Nitrate of soda was applied at the rate of 309 pounds per acre, and sulfate of ammonia at the rate of 232 pounds per acre. Superphosphate at the rate of 600 pounds per acre and muriate of potash at 150 pounds per acre were worked into the soil along the rows immediately after planting. All plants made an excellent growth, and no differences between plots were observed during the summer.

Work not on a Project Basis. As in previous years, work has been done along lines not definitely classified under the various listed projects. This is mostly by members of the Pomology Department not on the Station Staff. The principal work along these lines is briefly mentioned.

The "Set" of McIntosh Apples in Middlesex and Worcester Counties. In the spring of 1929 county extension services and certain growers in these two counties reported that McIntosh apples failed to set properly and asked for assistance from the Experiment Station. Prof. Bailey and Mr. Roberts spent some time in these two counties cooperating with the county agents in studying this situation. Considerable data were collected and these indicated that the set was not as poor as had been reported. This observation seems to be supported by the fact that the crop at harvest was at least fair. The McIntosh is one of the varieties that blooms rather freely every year, but suffers a severe early drop. In this respect it stands in sharp contrast to the Baldwin, Wealthy, and many other varieties. In most years a light set of McIntosh is not serious, but in years when the set is naturally rather light, it results in serious limitation of the crop. The problem is a complicated one and it is planned to undertake some co-operative tests with various growers in these two counties in the season of 1930. It is believed that in this way information can be assembled that will help point the way to improved practices that may lessen the danger of light crops in years when the variety fails to set well.

A Study of the Storage of McIntosh Under Various Conditions. (O. C. Roberts in co-operation with C. I. Gunness of the Agricultural Engineering Department). The purpose of this study is to determine the relationship between temperature and the satisfactory storage of McIntosh apples. In conducting this experiment the apples were picked at various stages of maturity and placed in storage rooms with the temperatures at 45°, 40°, 32°, and air-cooled storage respectively. As a result of this experiment it is hoped that the maximum temperature at which McIntosh may be held satisfactorily will be determined.

Cross-Pollination and Sterility Studies with Certain Apple Varieties. (F. C. Sears, O. C. Roberts and others). Work on the cross-pollination of apple varieties was continued this year along similar lines as reported previously. McIntosh, Cortland and Northern Spy were used as the pistillate varieties. The pollen varieties included the McIntosh, Delicious Wealthy, Early McIntosh, Cortland, and Macoun. The last three, representative of McIntosh seedlings, were used especially on McIntosh. The results of this season's work showed Early McIntosh and Macoun as being of doubtful value as pollinizers for McIntosh, while Cortland was more satisfactory than the other two. However, the performance of Cortland was not as good as the previous year.

The effectiveness of the use of bouquets of suitable varieties on the set of McIntosh was studied. Two McIntosh trees were covered with tobacco cloth tents to exclude the possibility of natural pollination. A hive of bees was placed under each tree. Then a bucket containing a bouquet of Delicious, Wealthy, and Ben Davis flowers was placed in one of the trees, while in the other tree no pollen varieties were provided. The tree in which the bouquet was placed set approximately five times as many apples as the tree without the bouquet.

Studies of the Arsenical Residue on Apples. (O. C. Roberts cooperating with the Department of Entomology, and the Boston Federal Food, Drug, and Insecticide Administration). A study of the arsenical residue on apples has been continued this year as formerly with a few slight modifications. Dusts have been used in the later applications to determine if the use of such materials would control the pests and at the same time avoid an excessive deposit of arsenical residue. This appears to be a promising procedure.

DEPARTMENT OF POULTRY HUSBANDRY

J. C. Graham in Charge

Broodiness in Poultry. (F. A. Hays). The intense broody and the non-broody lines are being continued, and a considerable number of recessives lacking both genes for broodiness have appeared. As previously pointed out, there is some difficulty in increasing the population of recessives because of high mortality record. The wide variability in degree of broodiness in the broody line is receiving special attention at this time. The degree of broodiness in the flock as a whole has been reduced very significantly; first, by reducing the percentage of broody birds, and second, by decreasing the number of broody periods per individual.

The average length of the broody period has remained constant at fifteen days, throughout the history of the flock. The flock of 1927 showed only 9.5 per cent of the birds going broody as pullets. This places the flock on the same basis with respect to the broody trait as the White Leghorn.

Breeding Poultry for Egg Production. (F. A. Hays and Ruby Sanborn). The mean annual egg production of the 552 birds hatched in 1927 was 197.3 eggs. This flock was superior to previous flocks in early maturity, intensity and non-broodiness, but was slightly deficient in persistency. Records would indicate that the average decrease of eight eggs per bird was due to lack of persistency and to modifying environmental influences. The flock hatched in 1928 showed a very significant increase in vigor as measured by mortality rate in the laying house, the mean mortality rate for this flock being 14.85 per cent. The most significant increase was observed in flock hatchability for the spring of 1929, the mean percentage of fertile eggs hatched being 78, the highest in the history of the flock.

Age at first egg, body weight at first egg, high intensity and low broodiness have been well established in the flock. At the present time especial effort is being made to establish by genetic methods a flock lacking the winter pause and breeding true for genetic high persistency and high hatchability, together with maximum vigor.

Statistical Study of Heredity in Rhode Island Reds. (F. A. Hays and Ruby Sanborn). The data on the effects of inbreeding upon fecundity, covering a period from 1923 to 1928, have been assembled and submitted for publication as a Station bulletin. Eleven years' records on growth rate in Rhode Island Reds have also been assembled and are ready for publication as a Station bulletin.

A Genetic Study of Rhode Island Red Color. (F. A. Hays). Considerable progress has been noted in the establishment of desirable plumage color in the egg-laying strain of Rhode Island Reds. In the spring of 1929 a small flock of standard-bred Reds was obtained and will be used as a check against the Station strain in color breeding studies.

Determination of Genetic Laws Governing Results in Inbreeding Poultry. (F. A. Hays). A study, carried on for five years, of the effects of different degrees of inbreeding upon fecundity was concluded on March 1, 1929, and submitted for publication. The project is being carried on at present using as a foundation birds measuring up to the highest possible standard in characteristics affecting fecundity. The matings of 1929 consisted of sire on daughters in three different groups. The matings of 1930 will be made up using half-brothers and sisters. The same rigid standard for selection will be employed as long as the experiment continues.

Heredity and Environmental Characteristics Affecting Variability in Egg Production. (F. A. Hays). Data are now being accumulated under this project, and the second-year group of daughters are now housed to be tested for laying. The selection of the 1929 breeding stock was within the three lines established by the 1928 matings.

Factors Governing Egg Weight and Shell Character in Domestic Fowl. (F. A. Hays). The matings for 1929 in this project were made between individuals hatched in 1928 from the small, medium and large egg groups. The daughters hatched in 1928 from the mothers laying 52-gram eggs or 53-gram eggs in December did not show a significant difference in mean winter egg weight. On the other hand, the daughters from the mothers averaging 59-gram eggs in December showed a winter egg weight very superior to that of the other groups.

Egg weight in the entire flock has shown a very significant increase in the last two years. The flock hatched in 1928 reached a 24-ounce average in February. Egg weight records are now available for a complete year on 225 birds. A paper entitled the "Inheritance of Egg Weight in the Domestic Fowl" was published in the *Journal of Agricultural Research* for May 1, 1929.

Relation of Intensity or Rate of Laying to Feather Pigmentation. (F. A. Hays). Sufficient data under this project will be available next year for study. In a general way there appears to be considerable relation between intensity and shade of pigmentation in the Rhode Island Red.

DEPARTMENT OF VEGETABLE GARDENING

(Market Garden Field Station, Waltham)

Frank A. Waugh in Charge

Conditions Affecting the Production and Vegetative Propagation of Washington Asparagus. (V. A. Tiedjens). During the 1929 season investigations on the vegetative propagation of asparagus were continued. One-year-old roots weighing 160 pounds a thousand, and having crown bud development indicating high potential yielding power, were divided into two, three, four, and five or more crown sections. The results may be summarized as follows:

	Number planted	Number of skips	Number of stalks per plant	Average weight of roots *Grams*	Condition of growth
Whole crowns	144	0	8.4	88	Uniform height
Crowns cut in two	52	0	6.2	74	Uniform height
Crowns cut in three	52	3	5.8	62	Some variation
Crowns cut in four	78	17	6.1	50	Some variation
Crowns cut in five or more	26	2	5.5	61	Some variation

The skips in the above table are within reason except perhaps in the crowns cut in quarters. In this lot the number of skips is greater than usual. The size of the roots from the cuttings compares very favorably with the whole roots. Some of the roots from the cuttings were fully as large as the roots from the uncut crowns.

Due to the distribution and variation in size of buds on the crowns, it is impossible to make divisions so that each section from the same crown will have buds of equal size. The first buds developed on a seedling crown are much smaller than those developed late in the growing season. The small buds left over from the early seasonal growth are more or less dormant and will not produce as large a root growth as the sections having the larger buds that were developed late in the growing season. However, the potentialities for large root development are probably uniform for all the sections coming from the same root. The size of the buds on the cuttings is not necessarily correlated with the size of the stalks that follow. The size of the stalk is determined by the amount of stored food reserves in the roots attached to the section of the crown planted. The stalk may, therefore, be much smaller in diameter than the bud from which it came. The distribution of the buds on the crown determines where the crown may be divided, and thus the number of roots to the section is determined before the cutting is made. The plants that die may be accounted for by the section of the crown that they represent.

This method of propagation is feasible and applicable to commercial conditions. By this method it is possible to grow seedlings properly spaced, select 1,000 of the best out of every 10,000 roots, and increase these by crown cuttings to 3,000 or 5,000.

Comparison of Size of Roots.—A comparison between 100 two-year roots. 100 selected one-year roots, and 100 cull roots gave an average of 6.7 stalks per plant for the two-year-old roots, and 7.4 stalks for the selected one-year roots. The same number of skips, 3 per cent, was counted in each plot. In the plot of 100 cull roots the number of stalks per plant was 5.4, with 20 per cent skips. There was a big difference in height of stalks between the cull and selected one-year roots in favor of the selected roots. The two-year roots produced stalks slightly higher than the selected one-year roots.

Stem Cuttings.—An attempt was made to make stem cuttings on one and five-year-old plants. Cuttings were made from the stems below the branches having dormant buds and from the spears which had not broken open. These cuttings were grouped in four series, subjected to the following treatments, and placed in moist, sterile sand in a propagating frame.

Series I—Lot 1 immersed one hour in 3.8 per cent nitrate of soda solution; lot 2 immersed one hour in 1 per cent sodium thiocyanate solution; lot 3 immersed one hour in 3.8 per cent nitrate of soda solution plus 1 per cent corrosive sublimate solution; lot 4, check.

Series II—The time was increased to 2½ hours.

Series III—The same as Series II but the cut ends were sealed with low temperature paraffine.

Series IV—Immersed 6½ hours.

The spears in most cases decayed even when treated with corrosive sublimate, and proved very unsatisfactory as a source of material. None of the cuttings produced any signs of root growth, but considerable stem growth was made. The buds on the older part of the stem, that ordinarily are permanently dormant under field conditions, were stimulated to growth by the various treatments but did not show any material advantage over the check cuttings. Sodium thiocyanate for one hour was the most promising. Stalks from the one-year plants gave 30 to 50 per cent repsonse regardless of treatment, while the stalks from five-year-old plants gave 10 to 16 per cent response in growth of dormant buds. Sealing the ends of the stems gave no material difference except to make growth slower. There was considerable difference in bud and stem growth between cuttings from one and five-year plants.

On the whole the results were interesting but gave no information on root growth. The work will be continued another year along the most promising lines.

Plant Progenies.—Selecting from individual plant progenies for higher yielding plants was continued in the Martha and Mary Washington varieties. Thirty-three lots of seed, each lot representing a plant, were planted in the field in August, 1928, and a duplicate lot planted in the greenhouse February 8, 1929. Both were transplanted in the field in April, 1929, for comparison. The roots were spaced four inches apart. They were the same size in both cases, but the greenhouse lot was transplanted with green tops. The selections sown in the field varied from 51 to 100 per cent stand, while the greenhouse lot varied from 8 to 73 per cent stand. The average number of stalks per plant was 4.5 for the greenhouse lot and 5.8 for the field lot; the average number of stalks per plant varied from 3.0 to 6.8 for the various selections. This difference is probably an indication of the inherent vigor of the various mother plants.

There is a feeling among growers that the stalks of the Mary Washington variety break over more readily than the other varieties. This was noticeable in the plant progenies, for 7 out of 12 Mary Washington selections showed a sprawly growth, while none of the 39 Martha Washington selections showed the sprawly condition. This, apparently, is a weakness in the Mary Washington variety.

Number of Seeds to the Berry.—The average number of seeds to the berry varied from three to five in the different selections. A few berries on some plants had seven and eight seeds. The weight of 100 seeds varied from 1.6 grams to 3.2 grams.

The seed from one plant was grouped in six lots according to the number of seeds in the berry and was planted. The visible growth and percentage stand were best in the lot of seed coming from the two-seed berries. The seed of each lot was weighed, and the weight of 100 seeds decreased consistently from 2.6 grams for the single-seed berry lot to 2.0 grams for the six-seed berry lot.

The seed from three other plants was divided into four sizes with sieves. The weights in each case decreased as in the previous example. In each case the second heaviest, and the second largest seed, gave the most vigorous appearing plants. For a comparison, field run seed was screened into four sizes and planted with the four plants mentioned. In this group the growth made from the first and second largest seed was similar and did not show any advantage for the second largest seed, as was the case in the seed from the four plants. The consistency of this vigor in the second largest seed between the four plants seems to be significant and will be investigated further.

The results indicate the fallacy in comparing the effect of size of seed on plant growth by using field run seed. The variation in size of seed between plants makes it imperative that studies of this nature be conducted with seed from the same plant.

Field run seed was divided into large, medium, and small and planted three inches apart by hand in rows. The average stand (4 rows of each lot) was 61 per cent for the large seed, 70 per cent for the medium seed, and 64 per cent for the small seed. The consistency in stand in the individual rows of each lot makes the difference significant. The average number of stalks per plant for the three lots was not significantly different nor was there any difference in root growth.

Depth of Planting.—Two hundred selected one-year roots were planted 2, 4, 6, and 8 inches deep in 1928. The preliminary results are summarized in the following table:

Depth of planting	Skips	Number of plants		
Inches	%	Vigorous	Medium	Weak
2	2	165	28	3
4	9	144	30	8
6	17	120	33	13
8	30	65	38	37

These results were obtained on a medium silt loam with a gravelly subsoil. Four to six inches seems to be the best depth of planting to give a good growth and have the roots deep enough so that the surface can be cultivated in the spring.

Relation of Depth of Planting Seedlings to the Angle of Crown Growth. Seedlings starting their first storage roots were transplanted to the experimental plot. After a season's growth the roots were dug and the angle of inclination for the crown growth measured.

Depth of planting Inches	Sand	Medium sand and loam	Loam
1	—14.0°	—11.6°	—16.6°
2	—10.0°	—5.8°	—1.9°
3	+6.0°	+7.1°	+1.6°
4	+11.0°	+17.0°	+6.4°

The results show that the optimum depth for planting seed was between 2 and 3 inches for the three types of soil. At that depth the new buds on the crown developed horizontally. Shallower than 2 inches, the buds tended to develop below the horizontal plane, whereas at greater depths the buds developed above the horizontal plane.

Fertilizer Studies.—In the spring of 1929 fertilizer experiments on asparagus were started in Waltham, Concord, and Eastham. Five acres are devoted to the plots. A comparison of fertilizer ingredients, time of application of fertilizers, amounts of fertilizers to apply, relation of high phosphoric acid to maturity, and relation of fertilizer to earliness, are the main problems being investigated. Although there were variations between the plots at the end of the 1929 season, there was no correlation between the variations and the treatment of the plots. There was no consistency between duplicate and triplicate plots. The extremely dry season made it possible to locate the favorable spots in the field which were probably due to moisture.

Cold Resistance in Sweet Corn in Its Relation to Quality, Size, and Earliness. (V. A. Tiedjens). Breeding a cold resistant early yellow sweet corn was continued. A large number of ears were selected from a selfed lot of first generation seed. Considerable earliness has been incorporated in the Whipple Yellow strain used in the cross. Many of the F_1 selections were mature from two to ten days before the Whipple Yellow parent, and were fully as large.

Greenhouse Lettuce. (V. A. Tiedjens). Three pounds of the Bel-May greenhouse lettuce seed grown in 1929 were parceled out to growers in small quantities. Preliminary reports from the growers show this lettuce to be superior to Belmont and May King for greenhouse forcing.

Improvemenet of Vegetable Varieties Through Root and Seed Selection. (V. A. Tiedjens). Selection of foundation stock for the Field Station selection of the Wyman beet and Hutchinson carrot was continued. The demand for the Hutchinson carrot seed this year exceeded the supply by 400 pounds.

Thirty-one lots of Dwarf Horticultural beans from as many seedsmen, and fifteen lots of French Horticultural beans were compared, preliminary to establishing uniformity for these two varieties. Much mixture was found in most of the samples. Ten of the lots which showed some promise were saved for further study. There was considerable difference in earliness and susceptibility to drought between the two varieties.

Five samples of Blue Hubbard squash were secured for self-pollinating to establish a uniform variety of Blue Hubbard. A strain of Green Hubbard from the Vermont Experiment Station was grown and found to be very uniform for type characteristics. The season was not conducive to their development, however, so that the squash were under size. This was also true of the Blue Hubbard varieties.

The Genetics of Greenhouse Cucumbers. (V. A. Tiedjens). The work on this project has progressed along lines reported previously. Some crosses having commercial possibilities are being compared.

A new selection producing no pistillate flowers during the summer months and only an occasional pistillate flower during the winter months has been isolated and is being studied in crosses to determine how prevalent the sterility may become in commercial houses. The factor for this character probably had its origin in the English variety and may account for low yielding plants in commercial houses, as most of the commercial varieties carry some English "blood".

Bitter Cucumbers. Preliminary studies have been made on the relation of fertilizer treatment to bitter cucumbers. Nitrate of soda, urea, calurea, and calcium nitrate were compared with and without manure. The plants were grown in half barrels, and the chemicals were applied as top-dressing every two weeks. The first cucumbers were picked April 20, and the first bitter cucumbers occurred after May 10. The tubs receiving no manure gave 31 per cent bitter cucumbers, while the manure tubs gave 42 per cent bitter cucumbers, with no difference between the chemical treatments. There was some correlation between bitterness and growth. Of the fancy fruit, 30 per cent were bitter; of the wasp shaped types 35 per cent were bitter; and of the seconds and nubbins 50 per cent were bitter. Generally, the more time that was required to mature the fruit, the greater was the possibility that it would become bitter. There was no correlation between the location of the cucumber on the vine and its flavor. Bottle-necked cucumbers had a 75 per cent chance of being bitter near the stem end.

DEPARTMENT OF VETERINARY SCIENCE

J. B. Lentz in Charge

The Cutaneous Vaccine for Fowl Pox. (N. J. Pyle). From the eighth to the twenty-first day following the use of vaccines, egg production was slightly decreased. In birds 68 days of age, gain of weight indicated that growth was not seriously affected and that the weaker vaccine appeared to be as efficient as the stronger, "standard" vaccine. An immunity duration of at least 371 days was established. Attenuation of the vaccine appeared to be associated with its glycerol content. Details of this work are in the printer's hands.

Laboratory Service—Pathology. (G. L. Dunlap). This service was used by 284 persons, of which number 112 made personal calls, either delivering specimens or discussing the reports of examination.

Of the 1,055 specimens examined, 1,002 represented poultry and the remainder consisted of other domesticated animals. Approximately one-fourth of the poultry specimens harbored intestinal parasites, led by coccidia. Avian tuberculosis and fowl cholera were entirely absent in the material submitted.

Trichuris ovis, a sheep parasite, and tetrameres, a poultry parasite, are being reported for the first time from this laboratory.

A diagnostic fee of two (2) dollars, to be paid before a report is issued, is associated with this service. Failure of payment accounts for 26 unclaimed reports.

This service deserves credit for valuable assistance given to the pullorum disease testing work.

Poultry Disease Elimination Law. (W. R. Hinshaw and E. F. Sanders; H. Van Roekel and K. L. Bullis). Control Series Bulletin 48 reports the 1928-29 Pullorum Disease Testing Season. Compared with the 1927-28 season, the respective increases are: 72,001 agglutination tests, 63,861 birds tested, 92 flocks, 90 negative flocks, and 72 flocks 100 per cent tested and negative. Similar comparison shows the average infection to be reduced 2.27 per cent.

The proper age to start testing birds has received some attention. Preliminary results, obtained from a limited number of flocks, seem to show that the disease can be eradicated just as efficiently when testing is begun before laying, as when testing is postponed until the flock is in production.

Among the reasons for failure to eradicate pullorum disease the following were found to have been operating in some Massachusetts flocks: not all birds on the premises were tested, retesting at intervals during the season was not practised, chicks which were hatched before the test had been completed were raised, positive birds were not removed from the flock (109 reports studied showed 84 positives left in 26 flocks), infertile eggs from untested flocks were fed, custom hatching with no discrimination against untested flocks was practised, and purchases were made without careful investigation regarding the pullorum disease status of the flock of origin.

The progress of this work has been due to no one particular factor. Poultrymen, extension workers, administrative officers, and members of the laboratory staff have appreciated the value of cooperative effort. During the year the laboratory has received 188 visitors, who wished either to discuss their own individual problems or to prepare themselves to assist other poultrymen. The Seventeenth Annual Poultry Convention, during the 1929 Farm and Home Week, gave an entire afternoon to this subject, and over 250 persons showed that close, personal contact of all concerned improves the service.

At this time no definite conclusions can be made regarding the 1929-30 season. The month of October, with over 100,000 tests, surpassed the record of any single previous month in the laboratory's history. The advantages of this early testing, to both the poultrymen and the laboratory, are so evident that no discussion is required.

Farm and Station Bang's Disease. The laboratory, in assisting this project, has recorded 972 agglutination tests.

PUBLICATION

General Bulletins

247 Biennial Report: For the Fiscal Years Ending Nov 30, 1927 and 1928. 55 pp. February, 1929.

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or printed manuscript.

248 Tomato Leaf-Mold: The Use of Fungicides for Its Control in Greenhouses. Guba, E. F. 24 pp. March, 1929.

The culture of greenhouse tomatoes is an important industry in Massachusetts, and the area devoted to this crop has increased considerably in recent years. Leaf-mold is the most serious disease affecting the crop. The loss of one to two months of pickings of the fall crop and one month of the spring crop as a result of this disease is common. Past recommendations regarding the proper choice of fungicides for its control are conflicting and not based on experimental evidence, and growers who have used fungicides have not obtained control. This investigation has considered the merits of different types of fungicides. An effective material, and a practical method of application, have been discovered which are recorded in this bulletin.

249 The Plum Curculio in Apples in Massachusetts. Whitcomb, W. D. 28 pp. March, 1929.

The plum curculio is the most injurious insect pest of apples in Massachusetts, frequently damaging more fruit than all other insects together. As a result of the heavy loss to fruit growers, studies of this insect were begun in 1926 in the eastern part of the State, and this bulletin reports the progress of the work to date.

250 The Consumer Demand for Apples. Jefferson, Lorian P. 18 pp. April, 1929.

The purpose of production is the satisfaction of the requirements of consumers. In order to meet them efficiently, it is necessary to know the character and extent of the demand. This type of investigation has received comparatively little attention, but the importance of such information becomes increasingly evident. It was in the hope of benefiting both grower and dealer that this study was undertaken.

251 Causes of Differences in Poultry Profits. Mighell, R. L., and Branch, F. H. 19 pp. May, 1929.

Records based on experience in poultry farming show wide differences in financial returns. It is assumed that these differences can be attributed to certain specific practices and conditions which may be subject to control or modification. This study was undertaken to determine the extent to which the various factors and conditions operated and were effective in influencing profit in the industry.

252 Supplements for Copper Fungicides. Holland, E. B., Dunbar, C. O., and Gilligan, G. M. 20 pp. June, 1929.

Ever since copper fungicides were introduced, numerous supplementary products have been recommended for incorporation in the spray with a view to remedying some real or fancied defect. The contradictory evidence presented by different investigators relative to various supplements may be due in part to differences in amount of substance employed, in method of preparation and of application, but more often to an insufficient number of replications with different crops under varying weather and soil conditions. The use of supplements is not warranted unless they reduce infection and consequent economic losses. This study was undertaken to determine the intrinsic and relative values of the materials recommended for use as supplements.

253 Milk Substitutes for Calves. Lindsey, J. B., and Archibald, J. G. 9 pp. July, 1929.

The production of milk for near-by consumption is the principal industry of Massachusetts dairymen. The maintaining of the herd is an ever-present problem. Some farmers prefer to purchase mature milkers and others to rear calves from their own cows. This Station has been studying the most economical and satisfactory method of growing the calf until four months of age, and presents the results of its findings in this bulletin.

254 The Preparation and Effectiveness of Basic Copper Sulfate as a Fungicide. Holland, E. B., Dunbar, C. O., Gilligan, G. M, and Doran. W. L. 27 pp. June, 1929.

Copper fungicides have been a subject for investigation during the past few years. This work comprises a study of chemical composition, physical characteristics and general effectiveness in field work, together with the use of various supplementary products. The main objective was the preparation of a Bordeaux substitute that could be readily suspended in water and used as a spray, or mixed with a free-flowing carrier and applied as a dust. The product must give a practical control of disease but not necessarily equal to a highly dispersed Bordeaux of the same copper content. The advantages of such a product in the saving of time, labor and equipment in preparation, and the gain in uniformity and stability of the spray mixture are evident. Since basic sulfates are generally considered preferable to basic carbonates, attention has been directed largely to them.

255 Studies in Mineral Nutrition. Lindsey, J. B., and Archibald, J. G. 16 pp. November, 1929.

It was formerly held that the dairy animal obtained sufficient mineral matter from the roughages and grains consumed. More recently, based on some experimental evidence, this opinion has been questioned, and many have advised the feeding of supplementary minerals in the form of ground bone, ground limestone and the like. In order to get additional light upon the subject. this Station has conducted experiments with growing and mature dairy animals and presents its findings in Part I of this bulletin.

As a part of the work, many determinations were made of the mineral constituents of the grains and roughages fed, and likewise of the amount found in the ordinary roughages grown in different sections of Massachusetts. These analyses are brought together in Part II of this bulletin.

256 The Cost of Government in Massachusetts, 1910-1926. Yount, Hubert W., and Sherburne, Ruth E. 68 pp. November, 1929.

The rapid increase in demand for public service, together with the resulting increase in taxes, has placed a severe strain on farmers in many Massachusetts towns. This study analyzes the costs of public service in such towns compared with larger towns and cities, and points out the more important handicaps under which small towns operate.

257 The Cutaneous Vaccine for Fowl Pox. Pyle, Norman J. 20 pp. December, 1929.

Investigation of fowl pox at this Station has for its purpose the determination of an efficient preventive and curative treatment for the disease. This is of vital importance to the Massachusetts poultry industry because the disease causes serious loss by decreasing egg production during the season when eggs are highest priced.

The study of the cutaneous vaccine, as here reported, included investigations of its efficiency, its practical use and method of administration, its action on body weight, temperature, and early egg production, and the duration of immunity which followed its administration.

258 Inbreeding in Relation to Egg Production. Hays, F. A. 48 pp. December, 1929.

For many years inbreeding has been successfully used in establishing poultry breeds where foundation stock was available only from very diverse sources. In recent years, however, work in this field has been confined largely to flocks of an established breed, and the value of inbreeding from such restricted foundation stock is questionable. The experiment here reported was planned to show the effect of various degrees of inbreeding within a so-called established breed—in this case Rhode Island Reds.

259 Rate of Growth in Rhode Island Reds. Hays, F. A., and Sanborn, Ruby. 20 pp. December, 1929.

In selecting birds for various purposes, poultrymen make extensive use of body weight as an index of the characteristics desired. The weight records presented in this report cover an eleven-year period on all living individuals in a flock bred primarily for high fecundity and show something of their significance. The results may serve as guides to the weights which may be expected in this breed if high fecundity is the chief goal, when methods of management and climatic conditions are comparable.

Control Bulletins

44 Inspection of Commercial Feedstuffs. Smith, Philip H., and others. 28 pp. November, 1928.

45 Inspection of Commercial Fertilizers. Haskins, H. D., and others. 47 pp. December, 1928.

46 Inspection of Agricultural Lime Products. Haskins, H. D., and Goodwin, M. W. 6 pp. December, 1928.

47 Seed Inspection. Smith, Philip H., and others. 11 pp. February, 1929.

48 Eradication of Pullorum Disease in Massachusetts, 1928-1929. Hinshaw, W. R., and others. 36 pp. July, 1929.

49 Seed Inspection. Smith, Philip H., and others. 55 pp. October, 1929.

50 Inspection of Commercial Feedstuffs. Smith, Philip H. 33 pp. November, 1929.

51 Inspection of Commercial Fertilizers. Haskins, H. D., and others. 61 pp. November, 1929.

52 Inspection of Agricultural Lime Products. Haskins, H. D., and DeRose, H. R. 8 pp. December, 1929.

Meteorological Reports

481-492, inclusive. Monthly reports giving daily weather records with monthly and annual summaries.

Reports of Investigation in Journals

(Numbered Contributions)

82 The Inheritance of Egg Weight in the Domestic Fowl. Hays, F. A. Jour. Agr. Research 38:511-519. May 1, 1929.

83 The Mineral Constituents of Cranberries. Morse, Fred W. Jour. Biol. Chem. 81:77-79. Jan., 1929. ✓

84 Effect of Heat on Malic Acid. Morse, Fred W. Jour. Amer. Chem. Soc. 51:1276-1279. April, 1929.

85 Lime Penetration Resulting from Surface Application to Pasture Land. Nelson, P. R. Soil Science 27:143-146. Feb., 1929.

86 A Water Culture Technic for Studies in Tobacco Nutrition. Beaumont, A. B., and Larsinos, G. J. Jour. Amer. Soc. Agron. 21:150-155. Feb., 1929.

87 Dental Defects in Relation to Child Nutrition. Davies, Esther S. Jour. Home Econ. 21:106-107. Feb., 1929.

88 Monograph of the Genus Pestalotia De Notaris, Part I. Guba, E. F. Phytopathology 19:191-232. Mar., 1929.

89 Does Root Selection Accomplish Its Purpose in Asparagus Culture? Tiedjens, Victor A. Proc. Amer. Soc. Hort. Sci. 25:37-40, 1928.

90 Cultural Practices and Green Asparagus. Tiedjens, Victor A. Proc. Amer. Soc. Hort. Sci. 25:31-35. 1928.

91 An Intensive System of Grassland Management. Parsons, C. H. Amer. Soc. Anim. Prod. Proc. 1928.

92 The Effect of Other Crops on Tobacco. Jones, J. P. Jour. Amer. Soc. Agron. 21:118-129. Feb., 1929.

93 Spraying for the Control of Onion Thrips. Bourne, A. I. Jour. Econ. Ent. 22:679-683. Aug., 1929.

94 Observations on the Carrot Rust Fly (*Psila Rosae* Fab.) in Massachusetts. Whitcomb, W. D. Jour. Econ. Ent. 22:672-675. Aug., 1929.

95 The Chemical Composition of Grass from Plots Fertilized and Grazed Intensively. Archibald, J. G., and Nelson, P. R. Jour. Amer. Soc. Agron. 21:686-699. June, 1929.

96 The Effect of Apple Blossom Removal on Flower Bud Formation. Bailey, John S. Proc. Amer. Soc. Hort. Sci. 25:198-201. 1928.

97 Deficiency of Magnesium the Cause of a Chlorosis in Corn. Jones, J. P. Jour. Agr. Research 39:873-892. Dec. 1, 1929.

98 Effects of Soil Temperature and Reaction on Growth of Tobacco Infected and Uninfected with Black Root Rot. Doran, William L. Jour. Agr. Research 39:854-872. Dec. 1, 1929.

99 A Comparison of Field Methods of Determining Soil Reaction. Beaumont, A. B., and Thayer, C. H. Jour. Amer. Soc. Agron. 21:1102-1108. Nov., 1929.

100 Further Evidence Concerning the Significance of Nitrogen in Soil Organic Matter Relationships. Sievers, F. J. Jour. Amer. Soc. Agron. 22:10-13. Jan., 1930.

Other Contributions to Journals

(Unnumbered)

Trends in the Dairy Industry of New England. Cance, A. E. Rpt. 3d Ann. N. E. Inst. Coop., 1929.

Tendencies in Milk Production in Massachusetts. Sherburne, Ruth E. (Joint author). Ann. Amer. Acad. Polit. and Social Sci. March, 1929.

Repair of Soil Filter Tubes. Larsinos, G. J., and Beaumont, A. B. Soil Sci. 27:243. 1929.

Computation of No-Filler Fertilizer Mixtures. Beaumont, A. B., and Knudsen, H. R. Indus. and Engin. Chem. 21:385-388. 1929.

Concentrated Fertilizers: Problems for the Chemist and Agronomist. Beaumont, A. B. Jour. Chem. Educ. 6:899-905. 1929.

Causes of Cull Apples. Doran, W. L., and Bourne, A. I. Mass. Fruit Growers' Assoc. Rpt. 1929.

Some Results of the Fruit Disease Survey in 1928. Doran, W. L. Mass. Fruit Growers' Assoc. Rpt. 1929.

Lowering Weight Texture Handicaps on Plant-Packaged Ice Cream. Wright, K. E. Ice Cream Trade Jour. 25: No. 2. 1929.

Increasing Package Acceptability. Wright, K. E. Ice Cream Field 15: No. 2. 1929.

Frozen Fruit for Ice Cream. Mack, M. J., and Fellers, C. R. Ice Cream Trade Jour. 25: No. 8. 1929. Also, Ice Cream Field 15: No. 4. 1929.

Utilization of Cold Packed Fruits in Ice Cream. Mack, M. J., and Fellers, C. R. Ice Cream Review 13: Nos. 1 and 2. 1929.

A New Beneficial Insect in Massachusetts. Whitcomb, W. D. Jour. Econ. Ent. 21:937-938. 1928.

Fruit Insects of 1928. Bourne, A. I. Mass. Fruit Growers' Assoc. Rpt. 1929.

When Are Meats and Fish Spoiled. Fellers, C. R. Amer. Jour. Pub. Health 19::389-392. 1929.

Cranberry Sauce Manufacture. Fellers, C. R., and Griffiths, F. P. Canning Age, Dec., 1928.

Mincemeat, A Diversified Food Product. Fellers, C. R. Fruit Products Jour. 8:9-11. Dec., 1928.

Simplified Sugar and Syrup Calculations for Preservers and Canners. Fellers, C. R., and Mack, M. J. Fruit Products Jour. 8:16-19. Mar., 1929.

Utilization of Cold Packed Fruits in Frozen Dairy Products. Fellers, C. R., and Mack, M. J. Fruit Products Jour. 9:8-11. Sept., 1929; 9:46-47. Oct., 1929.

A Canned Grapefruit Defect. Fellers, C. R. Canner, Oct. 19, 1929.

Glass Packed Chicken. Fellers, C. R., and Griffiths, F. P. Glass Packer 2:315-318. Aug., 1929.

Unwashed Containers as Canned Food Contaminants. Fellers, C. R. Glass Packer 1:92-94. Dec., 1928.

CHANGES IN STAFF, DECEMBER 1, 1928, TO NOVEMBER 30, 1929

Appointments

Bullis, Kenneth L., D.V.M., Assistant Veterinary Pathologist, Poultry Disease Elimination Law, October 28, 1929.

Gibbs, Charles S., M.S., Ph.D., Assistant Research Professor Veterinary Science, November 4, 1929.

Hughes, Mary C., Laboratory Assistant, Pomology, October 28, 1929.

Lindsey, Adrian H., Ph.D., Professor, Agricultural Economics, September 1, 1929.

Shilling, Katherine E., B.S., Laboratory Assistant, Agricultural Economics, April 1, 1929.

Van Roekel, Henry, M.S., D.V.M., Chief of Laboratory, Poultry Disease Elimination Law, August 13, 1929.

Zielinski, John B., Jr., B.S., Junior Chemist, Fertilizer Law, October 1, 1929.

Resignations

Barton, Rena L., Laboratory Assistant, Pomology. Died August 22, 1929.

Brown, Marian V., B.S., Research Assistant, Farm Management, October 12, 1929.

Dufresne, Virginia R., A.B., Laboratory Assistant, Agricultural Economics, March 1, 1929.

Goodwin, Marvin W., B.S., Junior Chemist, Fertilizer Law, September 30, 1929.

Griffiths, Francis P., B.S., Research Assistant, Horticultural Manufactures, transferred to Instruction March 1, 1929.

Hinshaw, William R., M.S., V.D.M., Chief of Laboratory, Poultry Disease Elimination Law, July 31, 1929.

Nelson, Paul R., M.S., Research Assistant, Plant and Animal Chemistry, September 21, 1929.

Pyle, Norman J., V.M.D., Assistant Research Professor, Veterinary Science, September 30, 1929.

Sanders, Ellmore F., D.V.M., Assistant Veterinary Pathologist, Poultry Disease Elimination Law, October 12, 1929.

Waite, Clifton B., Collector of Blood Samples, Poultry Disease Elimination Law, September 30, 1929.

Publication of this document approved by the
Commission on Administration and Finance

2500—4-'30. No. 8756.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 261 FEBRUARY, 1930

Ecological Studies of the Mexican Bean Beetle

By Harvey L. Sweetman and H. T. Fernald

Since 1921 the Mexican bean beetle has spread from its native habitat, the Southwest, over most of the East where it has also been very injurious to the bean crop. During 1929 it was found for the first time in Connecticut and Massachusetts. A study of temperature and moisture conditions necessary for the development of the insect is here used in an attempt to determine whether it is likely to become a serious pest under the climatic conditions prevailing in New England.

Requests for Bulletins should be addressed to the

AGRICULTURAL EXPERIMENT STATION,

AMHERST, MASS.

ECOLOGICAL STUDIES OF THE MEXICAN BEAN BEETLE

By Harvey L. Sweetman[1] and H. T. Fernald,

Professor of Entomology

The Mexican bean beetle, *Epilachna corrupta* Muls., is a native of southwestern North America. It has been a pest of beans in southwestern United States since about the middle of the last century. The beetle has spread over most of the East since 1921 and has been very injurious to the bean crop through most of its range. It was found in New England in 1929 in Connecticut and Massachusetts, having apparently spread from New York State. The insect is capable of becoming a very serious pest of the bean crop in New England if the environmental conditions prove to be favorable to its reproduction and spread. The data presented here are the results of a study of the influence of the physical environment upon the bean beetle.

Review of Ecological Literature

The ecological factors affecting the bean beetle have received very little attention from most workers. The discovery of the insect in Alabama in 1920 caused much speculation regarding the effects of climate on it.

Hinds (1920) stated that there were not any climatic or geographical barriers to prevent the pest from spreading, but later (1922) attributed the slow dispersal southward in Alabama to the prevailing winds. Montgomery (1920) thought that losses from the bean beetle were not great in the Southwest because of climatic and other conditions. This thought is somewhat misleading as serious injury is rather common in that territory. Howard (1922a) considered a temperature of 100° F. or over in dry weather to be very destructive, and found (1922b) that the larvae were killed in a few minutes when in direct sunlight if the temperature was above 90° F. Later (1924) death of the larvae was noted as occurring during heavy rains, but drouth was not thought to be injurious as long as the plants were green. Howard and English (1924) witnessed large numbers of the immature stages being destroyed during a hot, dry period, but this was due partially to lack of food and to exposure to direct sunlight. They found also that moist places were essential for successful hibernation and that the beetles migrated if the hibernating quarters became too dry. Howard (1922b, 1924) had emphasized the fact that the adults required moist, but well drained, places for successful overwintering. Later Howard (1927) in collaboration with Transeau (1927) found that the regions in which damage occurred in Ohio coincided with areas that were originally mixed mesophytic forest. The previous year De Long (1926) in Ohio had stated, "There is an ecological factor that is controlling very decidedly the distribution." Graf (1925) from a climatological study concluded that temperature and moisture were not important factors in limiting the distribution of the pest. Later (1928) he stated that low winter temperature alone could not be depended upon to control the pest. Eddy (1926) and Eddy and McAlister (1927) in South Carolina consider low humidity and high temperature very detrimental to the immature stages, and a high moisture environment beneficial. Eddy and Clarke (1929) note that warm, moist weather favors spring emergence from hibernation. Thomas (1924) in Alabama emphasized the importance of high moisture for hibernation and a temperature between 65° and 91° F. and relative humidity between 40 and 95 per cent for egg production. His records were not secured under controlled conditions. Pepper (1926) noted the destruction of immature stages in South Carolina during a heat wave. Marcovitch (1926) found that drouth destroyed the insect in Tennessee and was a more important limiting factor than cold. He considered the humid conditions of the East favorable to the pest. Douglas (1928) found that temperature alone would not cause emergence of the adults from hibernation quarters, but that moisture was essential and more important than temperature. Cecil (1928) stated that the beetle would successfully survive the winter temperatures prevailing in New York State. The writer (1929) demonstrated the necessity of humid conditions for the bean beetle to maintain itself in abundance, and showed that its distribution in the West, as well as the East, depended upon that factor.

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[1] Candidate for a graduate degree in Entomology.

All of the above conclusions are based upon outdoor observations where several possible factors may have been important in producing the results mentioned. A considerable difference of opinion between the various workers is evident, and some of the citations are decidedly misleading and contrary to fact, as will be brought out later. Accurate data of the physical factors affecting the immature stages are especially lacking.

Description of Stages and Injury

All stages,—eggs, larvae, pupae, and adults,—of the bean beetle are conspicuous in the field.

The eggs are pale or orange yellow in color, nearly elliptical in outline, and about twice as long as wide. They are attached at one end and laid irregularly in groups of about fifty on the under sides of the leaves.

The larvae have four instars, molting three times previous to the pupation molt. The newly hatched larvae are about 1.5 mm. long, pale greenish-yellow in color, with their bodies armed with spines. The developing and mature larvae are yellow, with six rows of spines which become strongly branched and black at the tips (Plate 1, B). When over half grown they appear to be "humped", the longest spines and thickest portion of the body being in the middle. The abdomen in all instars tapers to the anal segment which is produced to form a sucker-like apparatus by which the larvae are aided in clinging to the leaf, and by which they fasten themselves previous to molting.

The pupae are light yellow in color, spineless, and about the size of the adults. They hang head downward from the under surfaces of the leaves and are partly covered and protected by the shed larval skins, which are attached by the posterior end to the surface on which they are fastened.

The adults are robust, hemi-ovoid beetles with rather slender legs, and are about one-fourth of an inch in length and one-fifth of an inch wide. When newly emerged the color is yellow, gradually darkening with age to bronze or brownish. Each wing cover is usually marked with eight small black spots (Plate I, B).

Both the adult and larval stages are destructive (Plate I, B). The beetles cut irregular holes through the leaves, leaving portions of tissue and the larger veins. The larvae are voracious feeders, and do more harm than the adults. At first they feed in colonies near the old egg mass on the lower surface of the leaf, but soon become scattered as they crawl to other leaves in search of food. They consume the lower layers of the leaf, leaving the upper epidermis and large veins. The upper tissue soon dies and bleaches out, leaving a whitish skeletonized appearance (Plate I, A).

Seasonal History

The adults of the Mexican bean beetle emerge from hibernation in the spring after the advent of warm weather, and locate suitable food plants, principally beans. Egg-laying begins in about a week or ten days after their appearance, the eggs generally being attached to the under side of the leaves. Incubation of the eggs requires about ten days to two weeks. The larvae feed upon the leaves and pods for about three to five weeks, then attach themselves to the leaves and pupate; the adults emerge eight to twelve days later. The number of generations in a season is dependent upon the climatic conditions and length of season, varying from one to four in the different localities. The beetles enter hibernation in the fall in moist places, remaining dormant or semi-dormant, depending upon the region, until spring.

Food Plants

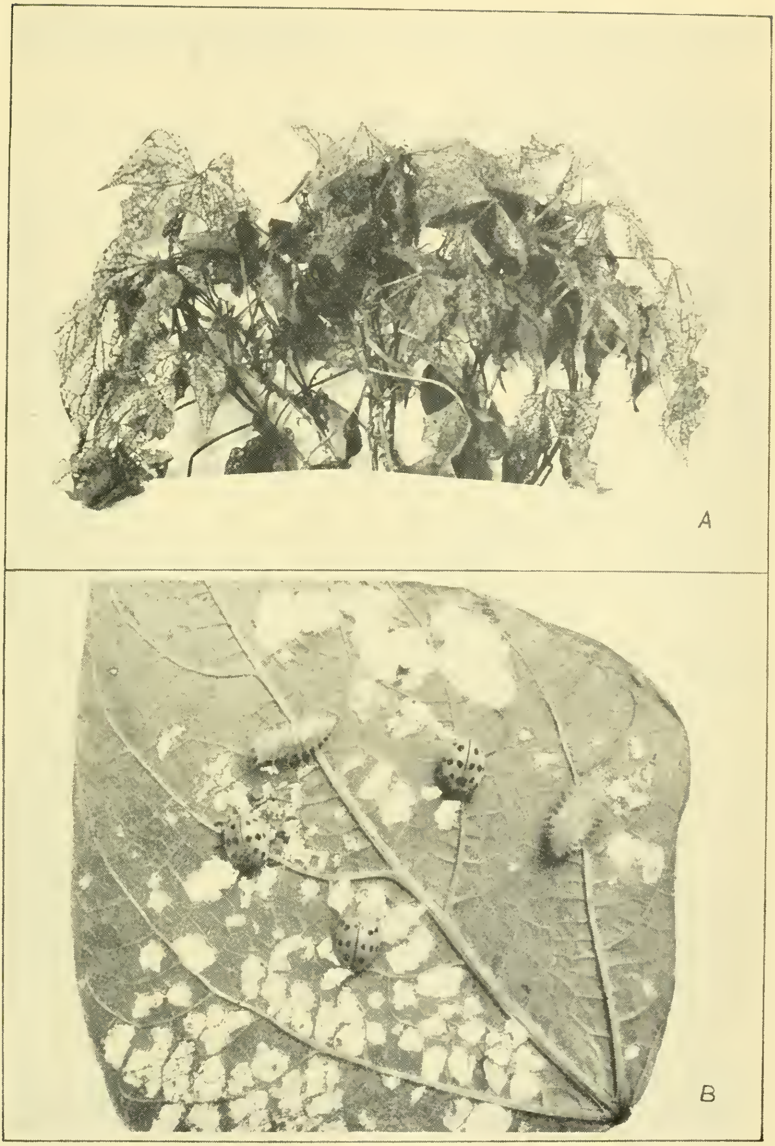
The bean beetle is primarily a bean pest, attacking by preference the common beans, including bush and pole varieties of snap beans, pinto, navy, lima, and tepary beans. It can subsist on a number of other plants and has severely injured cowpeas and soybeans in several states. Howard and English (1924) list the following plants as being attacked:

Common Name	*Scientific Name*
Tepary bean	*Phaseolus acutifolius*
Garden bean Including navy, pinto, kidney, pole beans, etc.	*P. vulgaris*
Lima bean	*P. lunatus*
Beggarweed	*Meibomia tortuosa,* *M. canescens,* *M. viridiflora*
Hyacinth bean	*Dolichos lablab*
Cowpea and Black-eyed Pea	*Vigna sinensis*
Soybean	*Glycine hispida*
Adsuki bean	*Phaseolus angularis*
Alfalfa	*Medicago sativa*
Sweet clover	*Melilotus alba*

Distribution

The bean beetle is a native of southwestern United States and Mexico. In the West it is now found in Wyoming, Utah, Colorado, Arizona, New Mexico, and Texas. It was discovered in Alabama in 1920 and has increased its range rapidly to the north and east since then. It spread to Georgia, Tennessee, North and South Carolina, and Kentucky in 1921; Virginia in 1922; West Vir-

PLATE I.



A. Bean Plant Injured by the Mexican Bean Beetle. B. Adult and Larval Stages and Feeding Injury on a Bean Leaf. (After Neale F. Howard, U. S. Bureau of Entomology).

ginia and Ohio in 1923; Pennsylvania, Indiana, and Mississippi in 1924; Maryland in 1926; New York, Michigan, and Ontario in 1927; Delaware and New Jersey in 1928: and Connecticut and Massachusetts in 1929. Unless some unusual climatic condition develops, the pest will probably reach eastern Massachusetts in the next two or three years.

Effects of Temperature and Moisture Under Controlled Laboratory Conditions

Biological Material.

Adults and Larvae. A stock cage of adults, feeding on growing plants, was kept in the greenhouse at all times. When experiments were started, beetles of about the same age and with similar previous history were used. The insects used in the original set of experiments were collected in late September and were of unknown ages and previous history. Care was used to proportion these beetles among the experimental cages according to the color, as the general body color becomes darker with age. The experimental cages were made of glass tubing about two inches in diameter, with the ends covered with cheese cloth, which permitted free access of air currents. The final method used for keeping the food fresh was to place the leaf petioles in a small vial of water. A grooved cork was used, to prevent evaporation from the vials affecting the cage conditions. By changing the leaves twice daily, the food was kept in excellent condition. Whenever the above method of handling the plants was not used, it is so stated when that experiment is considered. The larvae were cared for in a similar manner.

Eggs and Pupae. The eggs were handled by cutting away the surrounding leaf tissue and placing them in open vials. The drying of the leaf particles to which they were attached, and the consequent wrinkling sometimes injured a few eggs, and at times prevented some of the larvae from emerging, but this factor was considered when tabulating results. The pupae were treated similarly.

Physical Factors Involved.

Temperature is an extremely important factor in the life of the bean beetle. It is closely allied with moisture and does not affect the insect as a single factor except when approaching the high and low temperature limits. Moisture is as important to all stages of the insect as temperature, and in some stages is more so. It probably affects the insect principally through evaporation. The evaporation rate is in turn influenced by the temperature and air movement. The velocity of the air is extremely important, as the temperature and relative humidity about the plants approach a state of equilibrium with the environment away from the plants in direct proportion to the movement of the surrounding air. No direct effects of light on the bean beetle have been observed, but light is taken in indirectly through the food. It is extremely important to keep the insects supplied with fresh food. The larvae, especially, show signs of restlessness shortly after the plants begin to wilt.

Description of Apparatus.

A well-insulated cabinet containing six separate compartments was used. Each section was two feet by two feet by three feet in size. The top was made of glass so that the light intensity could be controlled from outside the cabinet. The doors, which were about two feet square, contained glass so that the insects and instruments could be observed without opening the compartments. The temperature was maintained with electrical heating units operated with thermostats, and cold running water, the two working against each other. Relative humidity was controlled by placing saturated salt solutions in wide pans, so as to have a large amount of surface exposed. In order to secure uniform conditions, fans were used to keep the air in motion. The fans were placed so that the air passed directly over the salt solutions. The experimental material was placed on wire shelves at about the middle of the compartment so that the air currents were directed through them, thus exposing the contents to the surrounding environment.

Environmental Conditions Obtained.

Temperature of any degree desired could be obtained, but relative humidity much below 32 per cent could not be secured. Generally a salt could be found that would give the approximate humidity sought above 32 per cent to nearly saturation of the atmosphere. All temperature records are in degrees centigrade, and moisture data in percentage of relative humidity.

These experiments were conducted as a part of the Mexican bean beetle project of the Wyoming Agricultural Experiment Station. Since the environments were controlled, the effects of temperature and moisture on the insect could not have been due to any geographical peculiarity in Wyoming.

Series of temperatures ranging from 17° to 37° at intervals of 5° were used. Moisture conditions varying from 32 to 93 per cent were maintained in the various temperature environments. Since it is impossible to discuss the effects of temperature on the Mexican bean beetle without taking into consideration the influence of moisture, the reactions of the insect to both factors are considered jointly.

Experiments with Adults.

Constant Conditions. A temperature of 37° was found to be above the maximum effective temperature regardless of the humidity that was maintained in the cabinets. Death resulted in every case in less than forty-eight hours, and the majority were killed in less than twenty-four hours (Table I, 37°). It is evident that the temperature alone was the major factor in destruction in this case, as death occurred in all humidity conditions used.

When a constant temperature of 32° was maintained, very interesting results were secured, as the interaction of both temperature and moisture are evident (Table I, 32°). Heavy egg production occurred in the dry environment, while the yield was exceedingly low in the moist conditions. The inhibitory action of a high humidity on oviposition was evident, as laying beetles in 92 per cent humidity discontinued deposition in the second week and all but one female was dead by the end of the third week. Non-laying beetles in 90 per cent humidity were not stimulated to egg production and all were dead by the end of the third week. All of the beetles were living at the end of five weeks in 32 per cent humidity. An earlier series with humidities of 40, 70, and 90 per cent gave results showing the same tendencies, but the data are not included in the table since the food was not kept fresh and starvation may have influenced the results in the dry environment. The amount of food consumed in 70 per cent humidity was much reduced, while very little food was consumed in the higher humidities in either series. Possibly the inability of the beetles to eliminate water in the high moisture environments was an important factor in producing death. These results show that a constant temperature of 32° can be very favorable to the oviposition rate and length of life of the bean beetle with a low humidity, and extremely unfavorable with a high humidity. When the beetles were varied between dry and wet environments, the number of eggs obtained was intermediate between the yields obtained in the constant conditions (Table I, 32° Moisture Varied). A calculation of the number of eggs to be expected according to the hours of exposure under regularly varied conditions of humidity, as determined by the results with constant humidity, gives figures which agree fairly closely with the actual number laid. Apparently the inhibitory action of 92 per cent humidity on egg production of the beetles was not carried over to any great extent into periods when the percentage of moisture was reduced to 32 per cent.

A temperature of 27° proved to be much more favorable to heavy egg production than 32° (Table I, 27° Moisture Constant). Three different series of experiments are given, but all of them show the same tendencies. The first series was made up of beetles of unknown ages collected in the field in September. Many of these beetles had been laying previous to exposure to the experimental conditions. Humidities of 60 per cent or above were favorable tc heavy oviposition, while a low humidity of 32 per cent showed a reduction of over one-half in the number of eggs deposited. A sufficient number of eggs was laid in the dry conditions for the bean beetle to maintain itself in numbers as far as egg production is concerned. A slight reduction in the egg yield occurred in 85 and 93 per cent humidity.

The varied moisture conditions gave results similar to the constant environments (Table I, 27° Moisture Varied). The beetles used in this series were collected in September after the natural oviposition period had ended. Many of the females had probably laid a large number of eggs previous to collection. A rather wide range of humidity appears to be suitable for good egg production at 27°, although a reduction in oviposition occurred in both high and low moisture environments. The two varied conditions in which the beetles were kept in 93 per cent humidity for sixteen hours show a markedly large reduction below the expected number of eggs, which is only partially accounted for by the death of a few of the beetles. This result indicates that this high humidity at 27° was slightly unfavorable to egg production.

The results secured at 22° were not as extensive as at 27°, but they are very similar in so far as they are comparable. Data from two experimental series are shown (Table I, 22°). One cage of beetles in the 40 per cent humidity showed a lowered egg production indicating a possible inhibitory effect in this low humidty. A similar decrease in egg production in the 90 per cent humidity cabinet indicated that this high moisture environment was still unfavorable, as was found with higher temperatures.

The results secured in the 17° environment with 50 per cent humidity are very important (Table I, 17°). Since this humidity is near a critical point between favorable and unfavorable moisture conditions for egg production at higher temperatures, care must be used in interpreting the data. It is quite probable that 17° is very close to the minimum effective temperature for oviposition of the bean beetle. This conclusion becomes more certain when the varied data are analyzed (Table II, 17°). The number of eggs laid appears

Table I.—The Effect of Moisture on the Adults of the Mexican Bean Beetle.

RELATIVE HUMIDITY—Per cent Daily exposure of			Number of beetles		Number of beetles died		NUMBER OF EGGS								Number of eggs expected
8 hrs.	16 hrs.	24 hrs.	♂	♀	♂	♀	1st week	2d week	3d week	4th week	5th week	6th week	7th week	Total	
							Temperature 37° C.—Moisture Constant								
	40		3	5	3	5	0							0	
	75		3	5	3	5	0							0	
	90		3	5	3	5	0							0	
							Temperature 32° C.—Moisture Constant								
		32	2	5	0	0	219[2]	521	501	650	326[3]			2217	
		90	3	5	3	5	0	0	0	....	.. .			0	
		92	2	5	2	4	49[2]	129	0	0	0[3]			178	
							Temperature 32° C.—Moisture Varied								
92	32		2	5	0	0	116[2]	414	545	294	179[3]			1548	1571
32	92		2	5	0	2	109[2]	112	173	202	144[3]			740	854
							Temperature 27° C.—Moisture Constant								
		32	10	16[1]	0	2	27	214	111	61				413	
		60	10	16[1]	1	0	0	92	374	535				1001	
		72	10	16[1]	0	0	55	249	134	328				766	
		93	10	16[1]	0	0	0	175	236	442				853	
		32	5	8	0	0	0	55	217	266	381			919	
		60	5	8	0	0	0	264	261	691	933			2149	
		72	5	8	0	0	0	451	458	733	694			2336	
		93	5	8	0	0	234	458	601	561	295			2149	
		62	3	5	0	1	53	218	460	484	414	157	290	2076	
		80	2	5	0	0	0	374	563	738	494			2169	
		85	3	5	0	1	0	237	227	167	406	289	514	1840	

Temperature 27° C.—Moisture Varied													
32	60		10	16[1]	1	2	53	46	245	506		850	805
32	72		10	16[1]	2	1	139	112	134	345		730	648
32	93		10	16[1]	2	4	0	185	109	15		309	706
60	32		10	16[1]	3	2	101	125	123	179		528	609
60	72		10	16[1]	2	3	111	263	116	490		980	844
60	93		10	16[1]	0	2	47	54	227	165		493	902
93	32		10	16[1]	1	2	107	256	258	525		1146	560
93	60		10	16[1]	2	3	0	119	434	511		1064	952
93	72		10	16[1]	2	0	0	36	206	477		719	795
Temperature 22° C.—Moisture Constant													
		40	3	5	0	0	53	104	253	318	321	1049	
		60	3	5	0	1	0	161	300	335	271	1067	
		90	3	5	0	0	0	49	97	225	111	482	
		40	2	5[2]	0	0	0	115	243	346	231[3]	935	
		86	2	5[2]	0	0	285	658	655	539	320[3]	2457	
Temperature 17° C.—Moisture Constant													
		50	2	5	0	0	0	58	0	59	39	156	

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[1] Beetles of unknown ages collected in September.

[2] Beetles four to six weeks old and laying at start of experiment.

[3] Beetles four to six weeks old and laying at start of experiment. Experiment closed in the middle of the fifth week.

to be in proportion to the number of hours the beetles were kept in the higher temperatures, indicating that very little, if any, stimulation to egg development occurred at 17°.

Varied Conditions. A number of experiments were planned to ascertain the effects of definitely varied conditions on egg yields. One factor, either temperature or moisture, was held constant, or approximately so, while the remaining one was varied. Temperature environments, which were easily controlled, ranged from 17° to 32° at intervals of 5° (Table II). Varied temperature conditions were obtained by transferring the experimental cages from one cabinet to another at definite intervals, a twenty-four hour day being divided into eight and sixteen hour periods. This process of alternation was continued day after day, so that each cage was in one environment for eight hours, another sixteen, then back to the eight hour condition, and so on, for the duration of the experiment. Moisture environments in two cabinets with different temperatures could not always be maintained with the same humidities, so that percentages of moisture as similar as possible were chosen. Thus combinations of high humidity percentages, as 86 and 92, 80 and 92, and 80 and 86, are considered approximately equal in their effects on egg production. Likewise combinations of low humidity percentages, as 32 and 40, and 40 and 50, can be considered as having similar effects on egg development. The one humidity combination of 32 and 50 per cent is considered as a varied moisture environment within the low humidity region. The experimental cages were transferred from one cabinet to another, as described above, when the effects of varied moisture conditions were sought. Data obtained from the cages that were kept in the constant environments are placed under each heading for comparative purposes. In each instance the beetles were taken from the same stock cages as those used in the varied surroundings. The data are arranged about the temperatures 32°, 27°, etc., so that a direct comparison can be made with the results from the constant conditions. This necessitates the repetition of some of the data in more than one place, but the discussion is not repeated unless necessary. An expected number of eggs was calculated from the data secured under constant conditions and placed in the last column of the table. These figures are based on the number of hours the beetles were kept in the respective temperatures and in high and low humidity, and serve as an aid in comparing the actual results obtained in the varied conditions with those secured in constant environments. A temperature of 37° was excluded from the varied experiments because of the disastrous results obtained under constant conditions.

The results obtained from varied temperature environments with 32° are given in Table II (32°). The humidity combinations, except 32-50 and 50-32, are considered as approximately constant. The total number of eggs laid by the beetles exceeded the expected number in every instance, but the excess was much greater in the high humidities. The reduced egg yield at 32° in the high moisture environments (Table I) seemed to be largely offset when the alternating temperature was reduced to 27° for sixteen hours daily, but was still evident with only eight hours' exposure daily at 27°. When 22° was used as the alternating temperature with 32°, the numbers of eggs laid were rather uniform in both high and low humidities. The results, 2057 to 2231 eggs, compared favorably with the number laid, 2217, in the 32° constant temperature cabinet with low humidity. When 17° was used as the alternating temperature in connection with low humidity, the number of eggs

Table 11.—The Effects of Varied Temperature with Approximately Constant Humidity on the Adults of the Mexican Bean Beetle

TEMPERATURE °C. Daily exposure of 8 hrs.	16 hrs.	24 hrs.	RELATIVE HUMILITY Per cent Daily exposure of 8 hrs.	16 hrs.	24 hrs.	Number of beetles ♂	♀	Number of beetles died ♂	♀	NUMBER OF EGGS 1st week	2d week	3d week	4th week	5th[1] week	Total	Number of eggs expected
								Basis of Comparison—32° C.								
		32			32	2	5	0	0	219	521	501	650	326	2217	
		32			92	2	5	2	4	49	129	0	0	0	178	
32	17		32	50		2	5	0	0	0	53	304	572	211	1140	843
17	32		50	32		2	5	0	0	0	298	564	439	399	1700	1530
22	32		40	32		2	5	0	0	354	530	629	412	201	2126	1790
32	22		32	40		2	5	0	0	0	499	724	615	393	2231	1362
22	32		86	92		2	5	0	0	169	568	403	635	282	2057	938
32	22		92	86		2	5	0	0	65	381	624	729	416	2215	1697
27	32		80	92		2	5	0	2	50	545	609	275	105	1584	842
32	27		92	80		2	5	0	0	104	506	575	694	236	2115	1505
								Basis of Comparison—27° C.								
		27			80	2	5	0	0	0	374	563	738	494	2169	
22	27		86	80		2	5	0	0	272	674	574	878	428	2826	2265
27	22		80	86		2	5	0	0	71	264	617	643	419	2014	2361
27	32		80	92		2	5	0	2	50	545	609	275	105	1584	842
32	27		92	80		2	5	0	0	104	506	575	694	236	2115	1505
								Basis of Comparison—22° C.								
		22			40	2	5	0	0	0	115	243	346	231	935	
		22			86	2	5	0	0	285	658	655	539	320	2457	
17	22		50	40		2	5	0	0	0	0	259	332	207	798	675
22	17		40	50		2	5	0	0	0	54	54	262	97	467	416
22	32		40	32		2	5	0	0	354	530	629	412	201	2126	1790
32	22		32	40		2	5	0	1	0	499	724	615	393	2231	1362
22	27		86	80		2	5	0	0	272	674	574	878	428	2826	2265
27	22		80	86		2	5	0	0	71	264	617	643	419	2014	2361
22	32		86	92		2	5	0	0	169	568	403	635	282	2057	938
32	22		92	86		2	5	0	0	65	381	624	729	416	2215	1697
								Basis of Comparison—17° C.								
		17			50	2	5	0	0	0	58	0	59	139	156	
17	22		50	40		2	5	0	0	0	0	259	332	207	798	675
22	17		40	50		2	5	0	0	0	54	54	262	97	467	416
17	32		50	32		2	5	0	0	0	298	564	439	399	1700	1530
32	17		32	50		2	5	0	0	0	53	304	572	211	1140	843

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[1] Experiment closed in middle of fifth week.

deposited was in proportion to the hours of exposure at 32°, showing that very little development of the eggs, if any, occurred at the lower temperature.

The stimulating effect of a varied temperature over a constant one is well illustrated by comparing the actual number of eggs found with the expected result. The fact that a varied temperature is more stimulating to developmental processes than a constant one is not new to science, but very few papers can be found which actually give data that demonstrate this. This conclusion shows that results obtained from constant temperature studies are inaccurate when compared with field conditions, but not necessarily impractical, as a great deal of information can be gained from such studies with a large saving in time, labor, and equipment.

Results were obtained from varied temperature environments about 27° with high humidity only (Table II, 27°). The stimulation to heavy egg production caused by varied temperature conditions is readily seen. The expected egg yield was not reached in one test, the 27°-22° combination. This result is probably not significant as the actual number of eggs laid in all other varied environments in the table exceeded the calculated results. The yield was markedly reduced when the beetles were exposed to 32° for 16 hours.

Varied temperature environments about 22° were much more complete than at 27° (Table II, 22°). Heavy egg laying resulted in all combinations of temperature above 17°. The large number of eggs (25 per cent more than was expected) produced in the 22°-27° condition was much greater than with any other set of temperatures and suggests that the optimum temperature is somewhere between 22° and 27°. The reduction in the number of eggs laid at a constant temperature of 22° with 40 per cent humidity was offset under varied temperature conditions above 22°. The wide range of humidity that was suitable for good egg production at 27° was equally satisfactory at 22° in combination with higher temperatures.

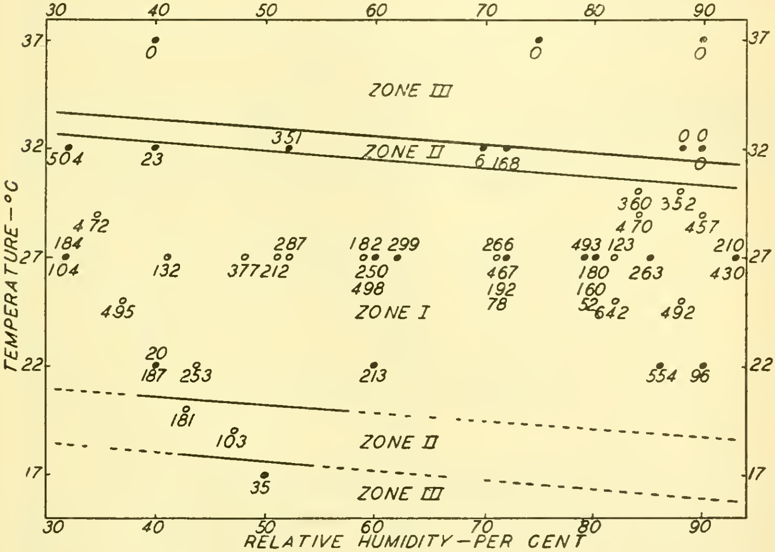
In Table I the minimum effective temperature was shown to be near 17°. When 17° was combined with higher temperatures good egg yields that exceeded expectations were found (Table II, 17°). It is evident that the bean beetle is capable of producing a sufficient number of eggs to maintain itself in numbers at low temperature between 17° and 22°, even when the humidity is below 50 per cent.

Constant and Varied Environments. The effects of temperature and moisture on the oviposition rate in both constant and varied environments can be further illustrated by plotting the data in Tables I and II (fig. 1). The figures represent the average number of eggs deposited per week in the various environments. More data are needed to determine accurately the limits in the low temperature and low humidity regions. However, general conclusions can be drawn from the data. Three zones are shown in the figure. The area marked "Zone I" probably covers the combinations of temperature and moisture in which the bean beetle is capable of producing a sufficient number of eggs to maintain itself in economic numbers, as far as egg production is concerned. Zone II represents the region where the insect probably will maintain itself, but not in economic numbers; while Zone III covers the conditions in which it will seldom be found. Keeping the beetles in variable environments enlarged the range of suitable temperature and moisture combinations over that obtained from constant conditions; but the results were essentially the same in other respects. The suitable temperature range for oviposition (about 12°) was quite narrow in comparison with the spread of favorable moisture conditions (about 60 per cent). It is apparent that it would require an extremely arid climate to lower the oviposition rates of the beetles sufficiently to reduce the numbers of the pest below that of economic importance. However, any reduction in oviposition, produced by arid conditions, would have an important influence on the total population if the conditions were dry enough to seriously affect larval development.

Summary. A temperature of 37° killed the adults in a few hours.

A temperature of 32° with high humidity was very destructive to the adults, but with low humidity was favorable to length of life and egg production. When alternated with lower temperatures the adverse effects were largely overcome below 27°, and partially offset at that temperature.

Figure 1. The Weekly Average Oviposition Rates of Beetles Maintained under Controlled Environments. ●—Constant Environments; ○—Varied Environments.



A temperature of 27° was favorable to length of life of the adults with all humidities used, and to egg production with moist conditions of 60 per cent or above. High moisture environments were more favorable than low humidity conditions, but the difference was not so great as with higher temperatures. When alternating temperatures were used with 27°, good egg production resulted with lower temperatures. Humidities of 93 per cent or above may be detrimental to egg production.

A temperature of 22° with humidities of 40 to 90 per cent was favorable to length of life of the adults and to egg production, although the number of eggs laid was reduced in the dry conditions. High egg yields with alternating temperatures resulted with all conditions above 17°.

A temperature of 17° was favorable to length of life of the adults but was near the minimum effective temperature for egg production. With alternating temperatures above 17°, the rate of oviposition was in proportion to the number of hours at the highest temperatures, the highest yields occurring in the 32° combinations with low humidity.

Experiments with Eggs.

Constant Environments. The results of incubating the eggs at 37° are given in Table III (37°). Three different humidity environments were used, but the eggs failed to hatch regardless of the moisture present, showing that a constant temperature of 37° is unsuitable for incubation of the eggs. The embryos not only failed to develop at this temperature but were killed, as later exposure to lower temperature conditions did not produce any development.

The incubation of the eggs at 32° gave results similar to those at 37° (Table III, 32°). Development failed to take place regardless of the humidity of the environment, showing that the failure to hatch was again due to the high temperature. An alternation of the eggs between wet and dry conditions did not change the results.

Table III.—The Effects of Moisture on the Eggs of the Mexican Bean Beetle.

RELATIVE HUMIDITY—Per Cent Daily exposure of 8 hrs.	16 hrs.	24 hrs.	Total number of eggs	Total number hatched	*Per cent hatched*	Days to hatch
Temperature 37° C.—Moisture Constant						
		40	276	0	*0.0*	....
		75	246	0	*0.0*	....
		90	221	0	*0.0*	....
Temperature 32° C.—Moisture Constant						
		32	411	0	*0.0*	....
		40	355	0	*0.0*	....
		70	477	0	*0.0*	....
		90	493	0	*0.0*	....
		92	353	0	*0.0*	....
Temperature 32° C.—Moisture Varied						
32	92		371	0	*0.0*	....
92	32		395	0	*0.0*	....
Temperature 27° C.—Moisture Constant						
		32	1700	0	*0.0*	....
		60	3175	773	*24.4*	6.0
		62	704	177	*25.0*	5.5
		72	3031	679	*22.4*	5.9
		79	1932	563	*29.3*	5.9
		80	335	34	*10.2*	5.5
		85	1059	155	*14.6*	5.8
		93	3195	953	*29.5*	5.7
Temperature 22° C.—Moisture Constant						
		40	494	0	*0.0*	....
		60	485	13	*3.0*	7.3
		90	398	146	*37.0*	6.8
		40	304	107	*35.2*	7.8
		86	365	227	*62.2*	6.6
Temperature 22° C.—Moisture Varied						
40	86		279	121	*43.4*	7.0
86	40		298	187	*62.8*	7.6
Temperature 17° C.—Moisture Constant						
		50	484	213	*44.0*	12.4

When the eggs were incubated at 27°, entirely different results were obtained (Table III, 27°). Larvae were secured in all moisture environments from 60 to 93 per cent humidity. The failure to hatch any larvae from 1700 eggs incubated under the 32 per cent moisture condition emphasized the unfavorable effects of a dry atmosphere at this temperature. The hatching periods of the eggs in the medium to moist cabinets ranged from 5.5 to 6.0 days, showing a close similarity in all conditions. The number of larvae hatching in the 80 and 85 per cent humidity environments was much below those in the other conditions, but the 79 and 93 per cent surroundings produced the best hatches, thus indicating that a moisture environment of 60 per cent humidity, or higher, at 27° is favorable to incubation of the eggs. The unfavorable limit would fall somewhere between 32 and 60 per cent humidity.

The effects of moisture on incubation of two different series of eggs at 22° gave rather irregular results (Table III, 22°). Probably the first series—40, 60 and 90 per cent—shows a much lower percentage of hatching than is normal for these conditions. When this series is compared with the results in Table IV (22°), which are in agreement with the second series of this table, the probability of an abnormally low percentage of hatching is made doubly certain. A much better hatch was obtained in the cabinets with high humidity. The incubation period was about one day less in the high than in the low humidity chambers, but was about one and one-half days longer than was required at 27°. The percentage of eggs hatching under most conditions at 22° was considerably above that at 27°, indicating that the former is a more favorable temperature. The alternation of eggs between wet and dry environments gave results similar to those obtained under constant conditions (Table III, 22° Moisture Varied).

The influence of a temperature of 17° with 50 per cent humidity was favorable to hatching of the eggs (Table III, 17°). Good hatching resulted but the incubation period was nearly twice as long as at 22°.

Varied Environments. A discussion of these environments is given under this heading for the adult stage. A high temperature of 37° was excluded from the varied series, as none of the eggs had hatched at that temperature in the constant environments (Table III).

The results of alternations of temperature with 32° are given in Table IV (32°). Combinations of 32° with 17° and 27° failed to produce any larvae regardless of the humidity used. When 22° was used, sixteen hours of exposure at 32° killed the embryos in both high and low humidity, but when the exposure was reduced to eight hours at 32°, one egg hatched in the low and 21.5 per cent in the high humidity. The number of eggs hatching in both cases was low, but is significant for the high moisture environment. Eggs hatched in about half of the egg masses used in this moist condition. This shows that a high moisture environment is preferable to dry conditions and may indicate that 22° is near the optimum temperature for incubation of the eggs. The incubation period of the single individual emerging in the drier environment was more than twenty-four hours longer than the average for those in the wetter condition. The longest incubation period in the high humidity cabinet was eight days.

The eggs were incubated in the varied conditions about 27° with high humidity only (Table IV, 27°). Good hatches were obtained from the eggs in the temperature combination of 27° and 22°, while either eight or sixteen hours at 32° was sufficient to prevent hatching of the eggs. The percentage of eggs hatching in the control cabinet was probably abnormally low as can be seen by comparison with the results in Table III. The length of the incubation period was approximately a day and a half below that at 32°. The number of days required for development was slightly less than the calculated figures.

When temperatures were alternated about 22°, good hatches were secured with 27° and 17° (Table IV, 22°). The poorest hatches were obtained in the 32° combinations where the unfavorable effects of the high temperature, previously discussed, were not fully overcome by eight or sixteen hours' exposure at 22°. The percentage of eggs hatching in low humidity conditions was much less than in high humidity environments, especially when the moisture content of the cabinet was below 45 per cent. The stimulatory effect produced by varying the conditions is shown in the table.

The data secured from varied conditions about 17° with low humidity are not as extensive as with 22° (Table IV, 17°). All of the eggs failed to hatch when exposed to 32° for eight or sixteen hours. When alternated with 22°, the percentage of eggs hatching was low in the drier environment, while the combination with humidity above 45 per cent gave much better results.

Constant and Varied Environments. The effects of temperature and moisture on the eggs can be illustrated further by plotting the data in Tables III and IV (figs. 2 and 3). The percentage of eggs hatching is given in Figure 2, and the length of the incubation period in Figure 3. The two figures are discussed together.

Three general zones are rather sharply defined, although more data are needed in the low humidity region between 22° and 17°. Under field conditions the region that falls below 17° is automatically taken care of by the negligible number of eggs laid below this temperature (Tables I and II); but from a scientific viewpoint it would be well to conduct experiments with temperatures below 17°. A suitable, intermediate, and unfavorable zone is indicated for the two conditions,—percentage of hatch and length of incubation period. It is evident that Zones I of the two figures do not agree. Since both factors are vital in the life cycle of the bean beetle, a position favorable to both of the above factors must be selected. The temperature limits then would fall on the upper line of Zone I of Figure 2 for high temperature, and the lower line of Zone I of Figure 3 for low temperature. This gives a decidedly small temperature range (about 6°) that is favorable for incubation of the eggs, although it must be remembered that lower temperatures merely delay the time of hatching and do not kill the embryos. The moisture limits are in much closer agreement in the two figures. The upper limit is not determinable from the data at hand, although favorable results were obtained in 93 per cent humidity. The lower limit probably falls between 40 and 50 per cent humidity. Thus the incubation period is shown to be an extremely vital one in the economic distribution of the bean beetle, as both high temperatures and low humidity are very destructive. However, low temperature is not necessarily detrimental unless continued for prolonged periods. The physical conditions just described would need to occur among the growing bean plants in the field to affect the eggs of the bean beetle.

Summary. A temperature of 37° destroyed the embryos in both wet and dry environments.

A temperature of 32° gave similar results in constant conditions, but with varied temperatures a few larvae hatched in the moist environment at 22°.

Table IV.—The Effects of Varied Temperatures with Approximately Constant Moisture Conditions on the Eggs of the Mexican Bean Beetle

TEMPERATURE °C. Daily exposure of			RELATIVE HUMIDITY—Per cent Daily exposure of			Total number of eggs	Total number hatched	*Per cent hatched*	Days to hatch	Expected number of days to hatch
8 hrs.	16 hrs.	24 hs.	8 hrs.	16 hrs.	24 hrs.					
Basis of Comparison—32° C.										
		32			32	411	0	*0.0*	....	....
		32			92	353	0	*0.0*	....	....
17	32		50	32		378	0	*0.0*	....	....
32	17		32	50		274	0	*0.0*	....	....
22	32		40	32		295	0	*0.0*	....	....
32	22		32	40		267	1	*0.4*	8.5	....
22	32		86	92		370	0	*0.0*	....	....
32	22		92	86		385	83	*21.5*	7.2	....
27	32		80	92		336	0	*0.0*	....	....
32	27		92	80		316	0	*0.0*	....	....
Basis of Comparison—27° C.										
		27			80	335	34	*10.2*	5.5	....
22	27		86	80		414	228	*55.1*	5.7	5.9
27	22		80	86		411	324	*78.8*	6.1	6.2
27	32		80	92		336	0	*0.0*	....	....
32	27		92	80		316	0	*0.0*	....	....
Basis of Comparison—22° C.										
		22			40	304	107	*35.2*	7.8	....
		22			86	365	227	*62.2*	6.6	....
17	22		50	40		315	87	*27.6*	8.9	9.3
22	17		40	50		413	258	*62.4*	10.2	10.9
32	22		32	40		267	1	*0.4*	8.5	....
22	32		40	32		295	0	*0.0*	....	....
22	27		86	80		414	228	*55.1*	5.7	5.9
27	22		80	86		411	324	*78.8*	6.1	6.2
22	32		86	92		370	0	*0.0*	....	....
32	22		92	86		385	83	*21.5*	7.2	....
Basis of Comparison—17° C.										
		17			50	484	213	*44.0*	12.4	....
17	22		50	40		315	87	*27.6*	8.9	9.3
22	17		40	50		413	258	*62.4*	10.2	10.9
17	32		50	32		378	0	*0.0*	....	....
32	17		32	50		274	0	*0.0*	....	....

Figure 2. The Percentage of Eggs Hatching in Controlled Environments. ●—Constant Environments; ○—Varied Environments.

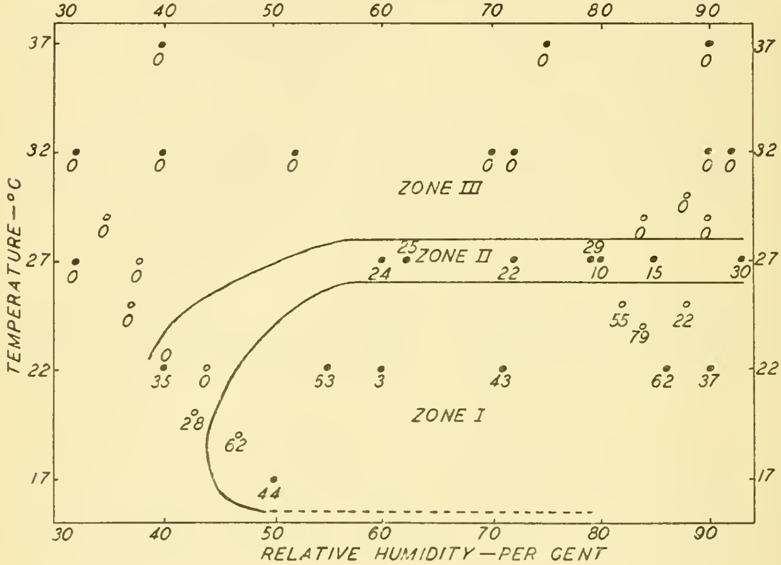
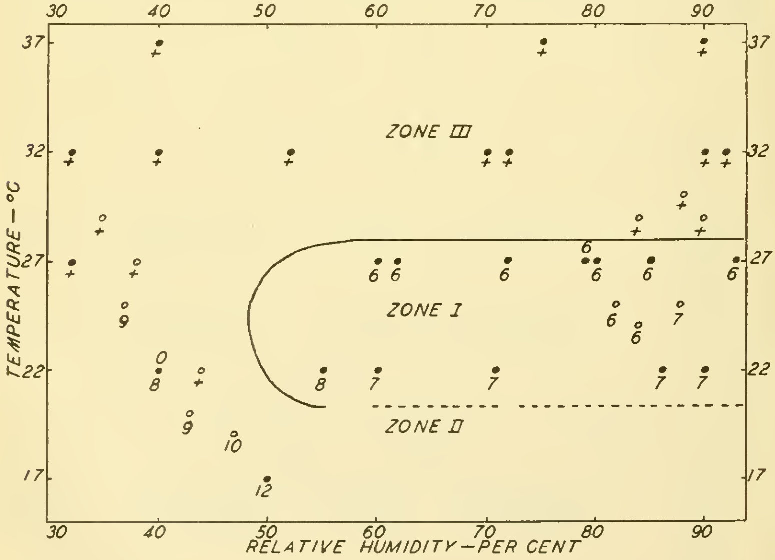


Figure 3. The Length of the Incubation Periods in Controlled Environments. ●—Constant Environments; ○—Varied Environments.



A temperature of 27° produced a fair number of larvae in moist surroundings but none in dry conditions with constant environments. Good hatches were obtained in varied conditions with 22°, but not with 32°.

A temperature of 22° produced good hatches in moist environments and with temperature combinations below 32°.

A temperature of 17° was favorable to good hatching of the eggs with humidity above 45 per cent and with temperature combinations below 32°.

Experiments with Larvae and Pupae.

Constant Environments. A high temperature of 37° was as disastrous for the larvae as for the egg and adult stages of the bean beetle, regardless of the humidity used (Table V, 37°). It is evident that the temperature is the limiting factor.

The effect of moisture on the larvae was brought out very clearly in the 32° series (Table V, 32° Moisture Constant). The results of two lots of experiments are listed in the table. The larvae in the first lot were fed at 8 a. m., 4 p. m., and 10 p. m., but the leaf petioles were not placed in water to keep the leaves fresh. A low humidity of 32 per cent was sufficiently favorable to enable half of the larvae to complete development. When the humidity was increased to 92 per cent, a few of the larvae reached the pupal stage but failed to transform into adults. In the earlier series where the food was not kept fresh, the same tendencies can be seen, as a few larvae were able to reach the pupal stage in 40 per cent humidity but none completed the feeding stage in the higher humidities. Undoubtedly starvation was an important factor in the earlier series. This is indicated by the lengthened feeding period that was required. Alternation of the larvae between dry and wet conditions gave slightly more favorable results than high humidity alone as a few of the larvae developed to the pupal stage (Table V, 32° Moisture Varied). The pupae in the high humidity were about one-half below normal in size. The adults that emerged in these conditions were undersized, and all of them were crippled. Some of the individuals had distorted wings or elytra, or both, while about 50 per cent had disfigured abdomens. The shrunken condition of the abdomens was noticeable with some individuals while still in the pupal stage. Much of the distortion was great enough to prevent mating and reproduction. Probably the moisture problem for the larvae is to eliminate moisture, since they take in large quantities of water with their food. This elimination would occur through excretion, respiration, and evaporation through the body wall. Excretion and respiration are probably the important means of water elimination. Loss of water through respiration would be greatly reduced in high humidity environments, and the process possibly might be reversed. This may be the explanation for the deaths of the larvae in high humidity conditions at 32°.

At 27° the larvae developed well, and the majority completed growth as long as the food was kept fresh (Table V, 27°). The data from three different series of experiments are shown in the table. The larvae in the first series were fed at 8 a. m. and 8 p. m. during the first part of the experiment, and at 8 a. m., 4 p. m., and 10 p. m. during the latter part of the experiment, but the food became rather dry at times. Fresh food was given to the second series at 8 a. m., 4 p. m., and 10 p. m., but the frequent feedings were not sufficient to keep the food fresh in the drier environments. Ninety-three per

Table V.—The Effects of Moisture on the Larvae of the Mexican Bean Beetle.

RELATIVE HUMIDITY—Per cent Daily exposure of 8 hrs.	16 hrs.	24 hrs.	Total number of larvae	Number of days feeding	Number of days as prepupae	Number of days as pupae	Total number of days	PER CENT REARED Prepupae	Pupae	Adults
				Temperature 37° C.—Moisture Constant						
		40	48	3	0	0	....	0.0	0.0	0.0
		75	28	2	0	0	....	0.0	0.0	0.0
		90	28	2	0	0	....	0.0	0.0	0.0
				Temperature 32° C.—Moisture Constant						
		40	62	25.1	...	...	....	14.5	14.5	0.0
		70	15	...	...	0	0	0.0	0.0	0.0
		90	71	...	...	0	0	0.0	0.0	0.0
		32	16	16.8	1.7	4.7	23.2	62.5	62.5	50.0
		92	59	17.9	...	...	....	6.6	0.0	0.0
				Temperature 32° C.—Moisture Varied						
32	92		24	21.0	2.0	...	....	16.7	8.3	0.0
92	32		28	17.0	1.5	...	....	7.1	7.1	0.0
				Temperature 27° C.—Moisture Constant						
		32	100[1]	...	...		....	3.0	3.0	3.0[1]
		60	223	22.7	7.0		29.7	22.0	22.0	17.0
		72	120	23.5	6.9		30.4	16.0	16.0	10.0
		79	101	23.5	7.3		30.8	22.0	22.0	20.0
		93	87	17.7	7.0		24.7	39.0	39.0	38.0
		62	47	13.8	6.8		20.6	63.8	63.8	63.8
		85	37	13.7	6.1		19.8	73.0	73.0	73.0
		80	14	14.8	1.8	5.1	21.7	92.8	92.8	92.8

				Temperature 22° C.—Moisture Constant						
		40	36	21.6	9.4		31.0	86.1	86.1	86.1
		60	36	19.7	8.9		28.6	66.6	66.6	66.6
		90	22	17.9	9.0		26.9	90.8	90.8	81.8
		40	13	20.0	2.6	6.7	29.3	92.3	92.3	92.3
		86	13	15.4	2.2	6.5	24.1	92.3	92.3	92.3
				Temperature 22° C.—Moisture Varied						
40	86		25	18.4	2.7	6.8	27.9	88.0	88.0	(88.0)[2]
86	40		30	20.2	2.6	. . .[2]	. . .	83.4	(83.4)	(83.4)
				Temperature 17° C.—Moisture Constant						
		50	8	30.4	3.9	11.1	45.4	87.5	87.5	87.5

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[1] Approximate figures.

[2] Experiment closed before development was completed. Probable results in parentheses.

cent of the larvae in 80 per cent humidity, which were supplied with fresh food, completed development. The food was near normal field conditions in this case, although the water content of the leaves possibly may have been slightly increased. The second series of larvae showed as rapid development as the first, but the number maturing under these conditions was about 20 per cent less than with the third, indicating that the drying out of the food between feedings may have been detrimental. The first series had the greatest range of moisture environments. The detrimental influence of the drying out of the food was very noticeable, the length of the feeding periods being about 30 per cent longer and the percentage maturing greatly reduced when compared with the results where the food was suitable. Probably the results obtained in 32 per cent humidity were due largely to starvation rather than to the dry atmosphere. A part of the data from the larvae reared in 32 per cent humidity was lost, but the estimated figures given in the table are very close to the actual results obtained. A great majority of the adults reared at this temperature were normal in size and appearance.

Two different series of larvae were carried through the developmental cycle at 22° (Table V, 22° Moisture Constant). The effects of moisture are shown in the length of the growing periods, being several days less when the humidity was high. A greater percentage of the larvae reached maturity in both high and low moisture environments. It is evident that a temperature of 22° with humidity ranging from 40 to 90 per cent was favorable for larval development. The adults reared in these environments were normal in appearance, but those developing in the high humidity conditions averaged somewhat larger in size than those which reached maturity in low moisture environments. This result may have been produced by the better quality of the food in the moist cabinets. Alternation of the larvae between the dry and wet surroundings made very little change in the results (Table V, 22° Moisture Varied).

A temperature of 17° also was suitable for a large percentage of the larvae reaching maturity, but about 40 per cent more time was required for them to complete development (Table V, 17°). Only a few larvae were reared at this temperature, but a check lot of fifteen larvae had nearly completed the feeding stage when the experiment was closed, indicating that the results in the table are normal. The adults obtained were large in size and normal in appearance.

The larvae reared in the 17° environments became quite dark in color. During the feeding periods most of the spines were gray or black in color, but the body surface largely remained yellow. The pigmentation increased with age and did not seem to be lost in molting. The cast skins appeared to be clear and free from coloring matter. The pigment was retained by the pupae, the greater part of the body surface appearing as gray or black in color, but on transformation adults of the usual color pattern emerged. Thomas (1924) observed the same effect when the larvae were reared during the cooler part of the season. The black spots on the elytra of these beetles apparently were not any larger than those on specimens reared at higher temperatures. The accumulation of the pigment was probably caused by the low metabolic rate of the larvae when reared at 17° which was not sufficient to oxidize all of the melanin formed (Knight, 1924).

Varied Environments. Larvae were reared under varied conditions of temperature ranging from 17° to 32° and a moisture spread from 32 to 92 per cent humidity. The food was kept fresh in all conditions by placing the leaf petioles in water.

The influence of alternating temperatures with 32° and approximately constant moisture surroundings was more favorable for larval development than constant high temperature (Table VI, 32°). When 27° was alternated with 32°, sixteen hours of exposure daily in the higher temperature proved to be very severe on the pupae as well as on the larvae. Eight hours' exposure daily was largely overcome by the cooler condition, as only a few larvae were killed. The use of 22° as the alternating temperature with 32° when the moisture was high gave results indicating that the influence of the low temperature overcame the adverse effects of the high in proportion to the hours of exposure in each. When dry conditions were used, the data were similar to those obtained in the check environments. The humidities in the 17°-32° environments were 32 and 50 per cent, and while both are low, they cannot be considered as constant. Good rearings were secured in these conditions.

The adults reared in the 17°-32° alternating environments showed a high percentage of distortion, only about 30 per cent appearing to be normal, indicating that most of the development took place in the higher temperature. Abdominal disfigurement was evident in about half of these insects. A few of the beetles were reduced in size. When 22° was alternated with 32°, sixteen hours of exposure daily at 32° produced about 60 per cent of normal individuals in both high and low humidity, and eight hours of exposure daily developed 80 per cent of adults normal in size. The alternation of 32° and 27° produced 12 per cent of normal adults with sixteen hours of exposure daily at the high temperature, and 80 per cent of normal beetles with eight hours' treatment daily at this temperature. Many of the adults were reduced in size in this latter environment.

The results of alternations about 27° with high humidity were quite uniform and favorable to development of the larvae of the bean beetle with the exception of sixteen hours' exposure daily at 32°, which has been discussed previously (Table VI, 27°). The adults reared in 27°-22° temperature conditions were normal with eight hours' exposure daily to 27°, but about 40 per cent of them showed some distortion of the wings and elytra following sixteen hours' exposure daily to 27°.

The influence of alternating temperatures about 22° with approximately constant moisture environments is shown in Table VI, (22°). The unfavorable effects of both high temperature and low humidity are shown, fewer larvae reaching maturity with an increase in the number of hours at 32° and in the lower humidities. However, a sufficient number of larvae developed in all of the environments for the beetle to maintain itself in economic numbers. Most of the adults that developed were normal in size and contour in all conditions below 32°.

The data in Table VI (17°) show the influence of alternations in temperature about 17°. The lengthened developmental period shows that these environments were inferior to the 22° and 27° conditions for rapid growth, although the death rate was very low. The adults reared under the 17° constant temperature environment were large and normal in appearance, while many of the beetles reared in the 17°-32° temperature combinations were greatly distorted.

The melanism that occurred under constant exposure at 17° did not appear when the larvae were alternated between 17° and higher temperature en-

Table VI.—The Effects of Varied Temperature with Approximately Constant Moisture Conditions of the Larvae of the Mexican Bean Beetle.

TEMPERATURE °C. Daily exposure of			RELATIVE HUMIDITY Per cent Daily exposure of			Total number of larvae	Number of days feeding	Number of days as prepupae	Number of days as pupae	Total number of days	PER CENT REARED		
8 hrs.	16 hrs.	24 hrs.	8 hrs.	16 hrs.	24 hrs.						Prepupae	Pupae	Adults
Basis of Comparison—32° C.													
		32			32	16	16.8	1.7	4.7	23.2	62.5	62.5	50.0
		32			92	59	17.9	0.0	0.0	0.0	6.6	0.0	0.0
17	32		50	32		24	17.3	2.1	6.1	25.5	87.5	87.5	83.3
32	17		32	50		16	21.2	2.9	......[1]	....	75.0	75.0	(75.0)
22	32		40	32		27	17.3[1]	1.8	5.1[1]	24.2	59.2	59.2	(59.2)
32	22		32	40		20	18.8	2.2	6.0	27.0	65.0	65.0	65.0
22	32		86	92		19	14.6	1.8	5.4	21.8	73.5	73.5	73.5
32	22		92	86		15	16.9	2.0	6.2	25.1	86.7	86.7	86.7
27	32		80	92		26	17.8	1.7	4.9	24.4	65.4	61.5	38.4
32	27		92	80		46	14.0	1.7	5.2	20.9	86.9	86.9	86.9
Basis of Comparison—27° C.													
		27			80	14	14.8	1.8	5.1	21.7	92.8	92.8	92.8
22	27		86	80		37	14.1	2.2	5.3	21.6	91.9	91.9	91.9
27	22		80	86		25	17.6	2.0	6.0	25.6	88.0	88.0	88.0
32	27		92	80		46	14.0	1.7	5.2	20.9	86.9	86.9	86.9
27	32		80	92		26	17.8	1.7	4.9	24.4	65.4	61.5	38.4
Basis of Comparison—22° C.													
		22			40	13	20.0	2.6	6.7	29.3	92.3	92.3	92.3
		22			86	13	15.4	2.2	6.5	24.1	92.3	92.3	92.3
22	17		40	50		12	25.0	3.2	......[1]		81.8	(81.8)	(81.8)
22	27		86	80		37	14.1	2.2	5.3	21.6	91.9	91.9	91.9
27	22		80	86		25	17.6	2.0	6.0	25.6	88.0	88.0	88.0
22	32		86	92		19	14.6	1.8	5.4	21.8	73.5	73.5	73.5
32	22		92	86		15	16.9	2.0	6.2	25.1	86.7	86.7	86.7
22	32		40	32		27	17.3	1.8	5.1	24.2	59.2	59.2	(59.2)
32	22		32	40		20	18.8	2.2	6.0	27.0	65.0	65.0	65.0
Basis of Comparison—17° C.													
		17			50	8	30.4	3.9	11.1	45.4	87.5	87.5	87.5
22	17		40	50		12	25.0[2]	3.2	......[1]	....	81.8	(81.8)	(81.8)
17	32		50	32		24	17.3	2.1	6.1	25.5	87.5	87.5	83.3
32	17		32	50		16	21.2	2.9	......[1]	....	75.0	95.0	(75.0)

[1] Experiment closed before development was completed. Probable results enclosed in parentheses.

[2] One larva feeding when experiment was closed.

Figure 4. The Length of the Developmental Periods of the Larvae and Pupae Reared in Controlled Environments. ●—Constant Environments. o—Varied Environments.

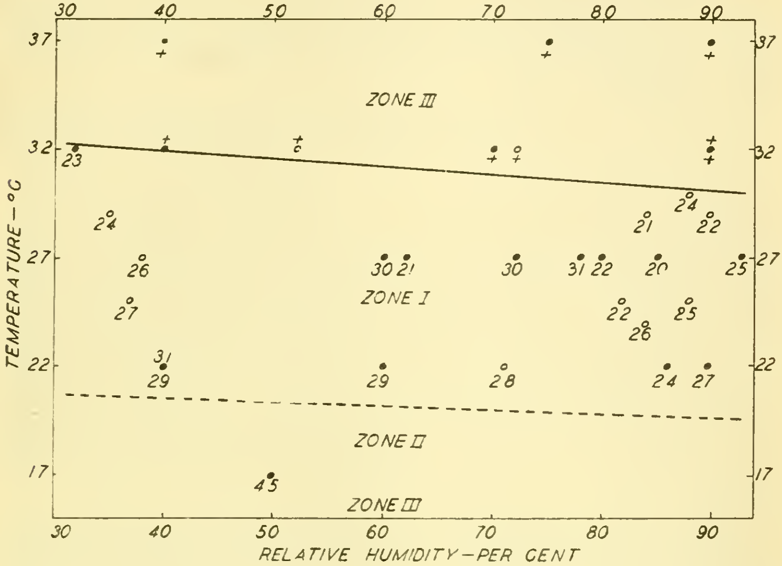
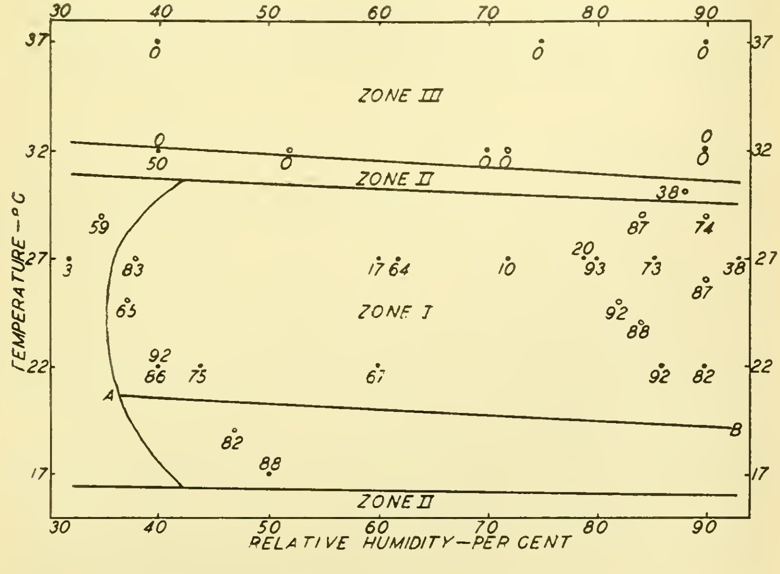


Figure 5. The Percentages of Larvae and Pupae Reaching Maturity in Controlled Environments. ●—Constant Environments. o—Varied Environments.



vironments. The increased metabolism occurring at temperatures above 17° was probably sufficient to oxidize the pigment.

Constant and Varied Environments. The effects of temperature and moisture on the larvae are shown graphically in Figures 4 and 5, which were constructed from the data in Tables V and VI. The length of the developmental periods was plotted in Figure 4 and the percentage of larvae reaching maturity in Figure 5.

The length of the developmental periods shows rather wide variations in environments that are very much alike. When development was completed at high temperatures, the time needed to reach maturity was favorable to the species. On the low temperature side the developmental period was greatly lengthened, indicating that a temperature below 20° would be rather unfavorable to the bean beetle. The average period was somewhat shorter when the humidity was high, but it is impossible to determine the limits of a suitable moisture range for length of developmental period from the data at hand. When the percentage of larvae reaching maturity is considered (fig. 5), the upper temperature limit of Zone I was one to two degrees below that in Figure 4, while the lower limit was still lower in comparison. The moisture limits are not indicated in Figure 4, but for the percentage of larvae reaching maturity (fig. 5) the lower limit was near 35 per cent. The moisture range, then, for favorable larval development lies between 35 and 95 per cent.

It is quite evident that neither the length of the developmental period nor the percentage maturing can be used as a criterion for determining the degree of favorableness for larval development necessary for the insect to maintain itself in economic numbers. Therefore a combination of Zones I of the two figures must be used. A high percentage of the larvae must complete development in a reasonably short time for the insect to maintain itself in abundance. Thus if a line is drawn from A to B (the lower limit of Zone I in Figure 4) in Figure 5, the resulting area of Zone I above this line would probably represent the combinations of temperature and moisture in which the bean beetle would become injurious in so far as larval development is concerned.

Summary. A temperature of 37° was very destructive to the larvae in all humidities used.

Half of the larvae completed development at a temperature of 32° when the humidity was low, while all of them succumbed in high moisture environments. The adults from larvae reared in these conditions were badly distorted. All of the larvae died in varied humidity at this temperature. The death rates were much reduced when the temperature was alternated, but most of the resulting adults were monstrosities.

A temperature of 27° was favorable for larval development with high humidity, while the death rate was very high in dry environments. Alternated environments with 32° were unfavorable.

A temperature of 22° was very favorable for larval development in all moisture conditions used. The number pupating was much reduced with 32° in the alternating temperature experiments.

A temperature of 17° was favorable for the larvae completing development, but growth was very slow. High percentages of the larvae matured in alternating conditions but the time necessary was greatly increased.

Suitability of the Climate of New England for the Bean Beetle

The practical value of the experimental data just presented can be estimated by a study of the climatological data for New England from the records of the United States Weather Bureau. Temperature and precipitation records from numerous places in this region have been secured for a number of years, and a few stations have been collecting relative humidity changes. The latter is more valuable in this study but, because of lack of sufficient material, precipitation records also will be used.

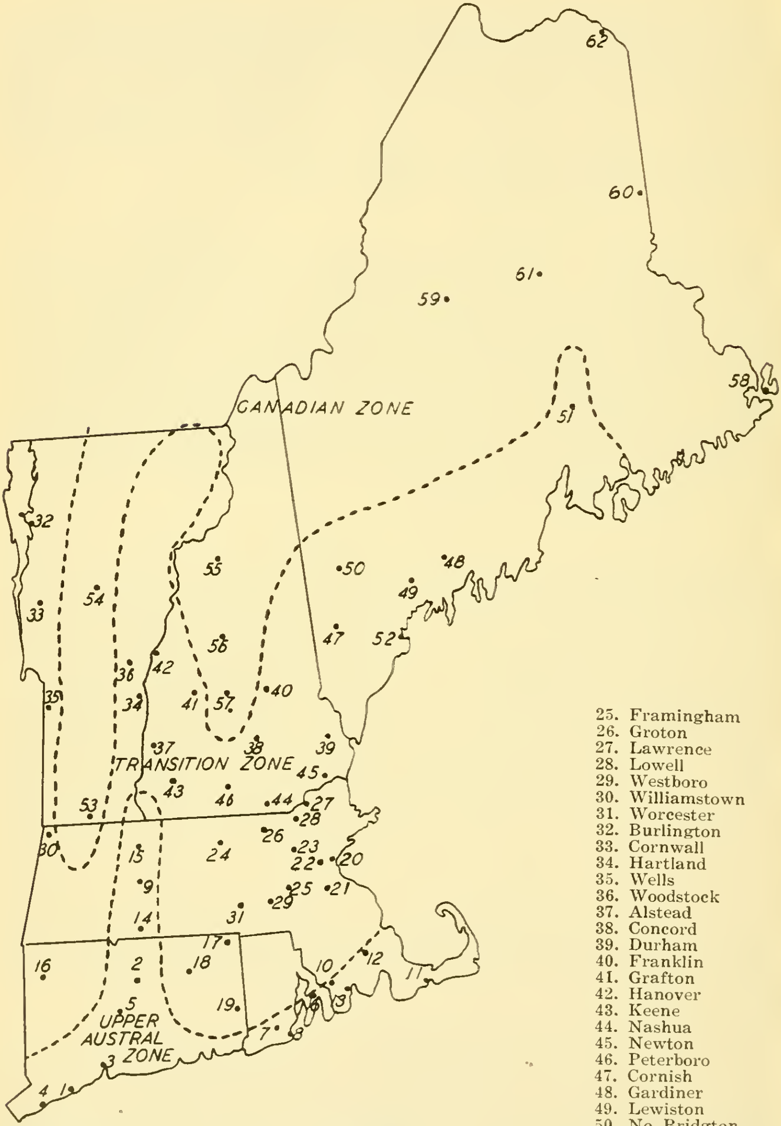
Faunal Zones of New England.

The faunal zones occurring in New England are the Canadian of the Boreal Region and Transition and Upper Austral of the Austral Region. These zones, as shown in the United States Biological Survey map of 1910 with modifications for New England by Fernald (1915 and later), are followed (Fig. 6). Meteorological data collected by the United States Weather Bureau stations within the various zones are used to determine the temperature and moisture conditions. Climatological data secured at places where the zones overlap are not used. Stations in the various zones selected as suitable for this study are shown in Figure 6.

Upper Austral Zone.—A composite climograph of temperature and moisture for the Upper Austral Zone is shown in Figure 7. The mean relative humidity is given in the climograph of Hartford, which is near the center of the Upper Austral Zone (fig. 8, Mean). The lowest humidity ordinarily occurs in the afternoon, and the 2 p.m. conditions plotted in Figure 8 (2 p.m.) approximate the driest part of the day. It is evident that the humidity is plentiful throughout the year, thus assuring suitable conditions for development of the eggs and larvae in summer and for hibernation of adults in winter. If the temperature becomes excessive during the summer months, the humid conditions would become unfavorable, but an examination of weather records shows that extreme temperatures are uncommon and of short duration. Maximum temperatures are ordinarily below 100° F. (37.8° C.) and, unless continuing for several successive days, the temperature among the plants fails to become injurious. Apparently conditions are favorable for the bean beetle to become a serious pest in the Austral Zone of Massachusetts, Connecticut, and Rhode Island. Beans are a rather common garden plant in this area. The insect is now found in this faunal division in southwestern Connecticut.

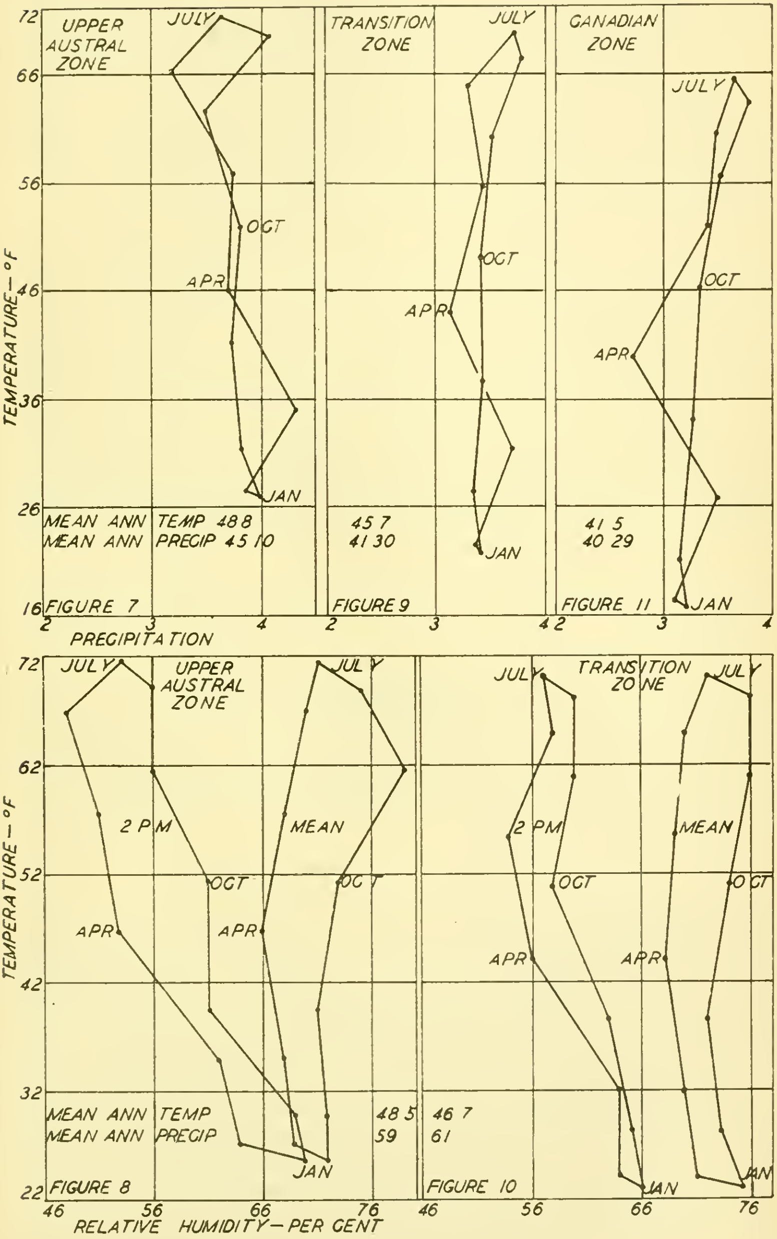
Transition Zone.—The mean temperature and precipitation are shown in the composite climograph for this Zone in Massachusetts, Connecticut, Vermont, New Hampshire, and Maine (fig. 9). A composite graph of the mean relative humidity and the 2 p.m. conditions of Boston, Portland, and Burlington are given in Figure 10 (Mean, 2 p.m.). The precipitation and relative humidity in Maine, Massachusetts, and Connecticut are very similar to that of the Upper Austral Zone just discussed. Since the temperature is slightly lower, less danger to the insect from the combination of high temperature and high moisture would exist. New Hampshire and Vermont are somewhat drier, but the heavier precipitation falls during the growing season and would be satisfactory for development of the immature stages. The winter months are sufficiently humid for successful hibernation of the adults.

Figure 6. The Faunal Zones of New England and Weather Bureau Stations in Each.


CANADIAN ZONE
TRANSITION ZONE
UPPER AUSTRAL ZONE
62
60
61
59
58
51
32
33
54
55
50
48
49
56
47
52
36
42
40
35
34
41
57
37
38
39
45
43
46
44
27
53
28
26
30
15
24
23
22
20
9
25
21
29
14
31
17
16
2
18
10
12
11
5
19
6
13
7
8
3
4
1

1. Bridgeport
2. Hartford
3. New Haven
4. Norwalk
5. Southington
6. Bristol
7. Kingston
8. Narragansett Pier
9. Amherst
10. Fall River
11. Hyannis
12. Middleboro
13. New Bedford
14. Springfield
15. Turners Falls
16. Cream Hill
17. No. Grosvenordale
18. Storrs
19. Voluntown
20. Boston
21. Blue Hill
22. Chestnut Hill
23. Concord
24. Fitchburg
25. Framingham
26. Groton
27. Lawrence
28. Lowell
29. Westboro
30. Williamstown
31. Worcester
32. Burlington
33. Cornwall
34. Hartland
35. Wells
36. Woodstock
37. Alstead
38. Concord
39. Durham
40. Franklin
41. Grafton
42. Hanover
43. Keene
44. Nashua
45. Newton
46. Peterboro
47. Cornish
48. Gardiner
49. Lewiston
50. No. Bridgton
51. Orono
52. Portland
53. Jacksonville
54. Northfield
55. Bethlehem
56. Plymouth
57. Sanbornton
58. Eastport
59. Greenville
60. Houlton
61. Millinocket
62. Van Buren

Figures 7, 8, 9, 10, 11. Composite Climographs of the Faunal Zones of New England.



Since the average temperature is somewhat lower than that of the Upper Austral, which ordinarily does not have excessive heat, it leaves the problem of determining if the temperature is high enough to favor reproduction. The mean monthly temperatures for July and August (fig. 9) for the Transition Zone are 69.7° F. (21° C.) and 67.4° F. (19.7° C.). These temperatures fall near the lower limits of suitability given in Figures 1-5 for the various stages. The beetle successfully overwinters in states that have as low temperatures as this area and apparently the bean beetle can be expected to become a pest over at least the southern part of the Transition Zone in so far as temperature and moisture are concerned, but may be restricted by lack of suitable food plants. As the northern limits of the Zone are approached, the injury will become less. The insect has recently been found in this faunal division in the Housatonic Valley of Connecticut and Massachusetts.

Canadian Zone. The climographs of temperature and precipitation for the portions of Maine, New Hampshire and Vermont in the Canadian Zone are given in Figure 11. The moisture of the environment appears to be satisfactory for the development of the immature stages. Very little danger to the pest would result from a combination of high temperature and high moisture conditions. However, the temperature alone would not encourage rapid development. The mean temperature of the warmest month, July, is 65.2° F. (18.5° C.). This means that the temperature would reach a favorable position for development for only a few hours daily and would not be sufficient for the beetle to become a pest. The insect may migrate into this area from the Transition Zone during the summer months and produce a limited amount of injury in local areas.

Discussion.

The conclusions that can be drawn from this study are based upon average conditions, and temporary variations from these will, of course, produce an environment either more or less favorable to the pest, depending upon the direction and duration of the variation. Local areas within the three zones may be found which do not have a temperature and moisture environment comparable to the surrounding region but such will not be sufficient to invalidate the general conclusions.

Food Availability in New England.

The principal food plant, beans, is common in Connecticut, Rhode Island, and eastern Massachusetts. This crop is localized in central and western Massachusetts and southern Maine, and is grown to a much less extent in New Hampshire and Vermont. Part of the Connecticut acreage is used for producing dry beans, but the growers in the remainder of New England market their product as string beans. The non-cultivated plants on which the bean beetle is known to develop belong to two genera, *Desmodium* (beggarweed) and *Crotolaria* (rattle-box), both closely related to beans (Thomas, 1924). One species of the latter, and at least seventeen of the former, are found in New England. Howard and English (1924) report *D. canescens*, a species found in New England, as being a suitable plant for larval development. These weeds may become important factors in the dispersal of the pest.

Conclusions

Adults. A temperature of 37° kills the beetles in a few hours; 32° is very unfavorable with high humidity and favorable with low humidity; 27° is suitable for heavy oviposition with humidity of 60 per cent or above and unfavorable with low humidity, but favorable for length of life with all humidities used; 22° is favorable with humidities of 40 per cent or above; and 17° with 50 per cent humidity is favorable for length of life but is very unfavorable for egg production.

Eggs.—A temperature of 37° kills the embryos; 32° is very destructive if reached for more than a few hours daily; 27° is suitable with humidities of 60 per cent or above and unfavorable with low humidity; 22° is very favorable with humidities of 60 per cent or above, but less favorable with low humidity; 17° with 50 per cent humidity is very favorable for good hatches, but development is very slow.

Larvae.—A temperature of 37° kills the larvae in a few hours; 32° is very unfavorable, especially with high humidity; 27° is favorable with high humidity and unfavorable with low humidity; 22° is very favorable with all humidities used; 17° with 50 per cent humidity is very favorable for a high percentage maturing, but development is exceedingly slow.

Climatic conditions in the Upper Austral Zone of Massachusetts, Connecticut and Rhode Island are favorable for the development of the Mexican bean beetle, and the insect may therefore be expected to become a serious pest. Conditions in the Transition Zone are less favorable, but the insect will probably become a pest in the lower portion of the Zone, with the injury becoming greatly reduced as the upper limits are approached. The Canadian Zone of New England does not have a physical environment suitable for the development of the beetle.

Literature Cited

Cecil, R.
1928. The Mexican bean beetle.
N. Y. (Geneva) Agr. Exp. Sta. Cir. 96:1-12.

De Long, D. M.
1926. (Discussion) Jour. Econ. Ent. 19:247-248.

Douglass, J. R.
1928. Precipitation as a factor in the emergence of *Epilachna corrupta* from hibernation. Jour. Econ. Ent. 21:203-213.

Eddy, C. O.
1926. The Mexican bean beetle in South Carolina.
Jour. Econ. Ent. 19:239-247.

Eddy, C. O. and McAllister, L. C., Jr.
1927. The Mexican bean beetle. S. C. Agr. Exp. Sta. Bul. 236:1-38.

Eddy, C. O. and Clarke, W. H.
1929. The Mexican bean beetle in 1927-8.
S. C. Agr. Exp. Sta. Bul. 258:1-41.

Fernald, H. T.
1915. Some present needs in economic entomology.
Jour. Econ. Ent. 8:36-38.

Graf. J. E.
1925. Climate in relation to Mexican bean beetle distribution. Jour. Econ. Ent. 18:116-121.
1928. Mexican bean beetle moves into new areas. Official Record 7:1, 3.
Hinds, W. E.
1920 Mexican bean beetle situation. Jour. Econ. Ent. 13:486-488.
1922. (Mexican bean beetle.) U. S. Bur. Ent. Insect Pest Survey Bul. 2:20.
Howard, N. F.
1922a. The Mexican bean beetle in its bearing on Florida citrus growing. Fla. St. Pl. Bd. Quart. Bul. 6:15-24.
1922b. The Mexican bean beetle in the southeastern U. S. Jour. Econ. Ent. 15:265-274.
1924. The Mexican bean beetle in the East. U. S. Dept. Agr. Farm. Bul. 1407:1-14.
1927. Correlation of Mexican bean beetle population with original forest type. Science 65:499-500.
Howard, N. F. and English, L. L.
1924. Studies of the Mexican bean beetle in the Southeast. U. S. Dept. Agr. Bul. 1243:1-50.
Knight, H. H.
1924. On the nature of the color patterns in Heteroptera with data on the effects produced by temperature and moisture. Ann. Ent. Soc. Amer. 17:258-272.
Marcovitch, S.
1926. Supplementary investigations of fluosilicates as insecticides. With observations on the effects of heat and drouth on the Mexican bean beetle. Tenn. Agr. Exp. Sta. Bul. 134:10-12.
Montgomery, J. H.
1920. (Mexican bean beetle in Alabama.) Fla. St. Pl. Bd. Quart. Bul. 5:2-3.
Pepper, J. O.
1926. (Mexican bean beetle.) U. S. Bur. Ent. Insect Pest Survey Bul. 6:109.
Sweetman, H. L.
1929. Precipitation and irrigation as factors in the distribution of the Mexican bean beetle, *Epilachna corrupta* Muls. Ecology 10:228-244.
Thomas, F. L.
1924. Life history and control of the Mexican bean beetle. Ala. Agr. Exp. Sta. Bul. 221:5-99.
Transeau, E. N.
1927. Vegetation types and insect devastations. Distribution of the Mexican bean beetle and European corn borer in Ohio. Ecology 8:286.

PUBLICATION OF THIS DOCUMENT APPROVED BY THE
COMMISSION ON ADMINISTRATION AND FINANCE

3 m-3-'30. No. 8164

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 262 FEBRUARY, 1930

Intensive Grassland Management

By R. C. Foley, E. J. Montague, and C. H. Parsons

An adequate and economical feed supply is a matter of vital importance in the success of livestock farming. The increased cost of farm labor and the higher price of concentrated feeds are two of the many factors which have upset economic relationships on many livestock farms, with the result that farm practices need to be modified if returns are to be increased or even maintained. The work reported in this bulletin was undertaken in the hope that it might result in the more profitable use of pasture land in Massachusetts.

Requests for Bulletins should be addressed to the

AGRICULTURAL EXPERIMENT STATION,

AMHERST, MASS.

INTENSIVE GRASSLAND MANAGEMENT[1]

By R. C. Foley[2], E. J. Montague, Assistant Professor of Animal Husbandry, and C. H. Parsons[2]

Introduction

Any profitable system of agriculture, if it is to be of a permanent character, must provide for the maintenance of soil fertility. The feeding of livestock and the return of the resulting manure to the land is one method whereby this may be accomplished. Profitable animal husbandry should provide for the home production of the greater part of the roughage fed and for the minimum use of expensive concentrates. Good pasture is the most economical method of producing feed for cattle during the summer months; yet pasture is frequently the most neglected crop on the farm.

Experimental work in pasture fertilization has been carried on at the Massachusetts Agricultural College for a number of years, but it was not until 1928 that the problem was attacked on a large scale. At that time an intensive system of grassland management, originally developed in Germany during the war, was inaugurated on the college farm. In 1916 while cut off from the rest of the world by the blockade, Germany began the home production of high protein feed for livestock through heavy fertilization of grassland with nitrogenous fertilizers. The system was developed by Professor Warmbold at the Hohenheim Experiment Station, using the following annual applications of plant food per acre: 107 pounds of nitrogen, 36 pounds of phosphoric acid and 80 pounds of potash. The phosphoric acid and potash and about half of the nitrogen were put on in February, while the balance of the nitrogen was applied in three summer top dressings of urea, a synthetic (air) nitrogen carrier. As a result of this treatment the area required was reduced from 1.4 acres per cow in 1916 to 0.75 acres in 1917 and to 0.5 acres in 1918. These results and the lower cost of synthetic nitrogen established the system in Germany, and it has since been quite generally introduced into the Netherlands and the British Isles.

The system is designed to provide a luxuriant growth of high protein grass, thereby making it possible for the dairy farmer, at least during the summer months, to produce on his own farm and in such a form that the cattle may harvest it directly most of the feed necessary for his herd. It was hoped that the application of this system to Massachusetts would effect a reduction in the amount of concentrates fed during the summer and yield greater returns per acre from the land used in maintaining the herd.

The system is based on four distinct principles, namely:

1. Division of area into plots.
2. Use of concentrated fertilizers.
3. Rotational grazing.
4. Combination of grazing and hay land.

---

[1] This demonstration was conducted with the cooperation of the Synthetic Nitrogen Products Corporation. Helpful suggestions were received from the Agronomy, Animal Husbandry and Farm Management Departments of the College.

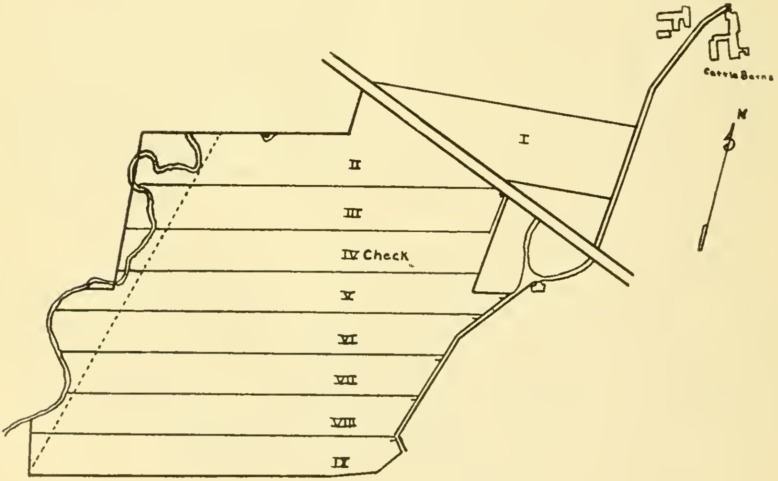
[2] Graduate students in Animal Husbandry.

The manner in which each of these principles has been applied at the Massachusetts Agricultural College during 1928 and 1929 is as follows.

Division of Area into Plots

Seventy-four and one quarter acres of land that had formerly been in a crop and pasture rotation (two years cultivated crop, one year hay and three years pasture) were divided and fenced off into nine fields of 8¼ acres each. Square plots are most desirable since cattle will graze more uniformly over such a field with less damage to the turf along the fence lines. However, the area available did not lend itself to this sort of division and the fields had to be somewhat rectangular. This division of the area into small plots offers a twofold advantage over the old system of large pastures. First, the cattle restricted to a small area will graze the entire area equally close thus preventing a tall growth of grass in certain portions which becomes unpalatable and will not be consumed until there is an actual shortage of good grass. Secondly, this system of small plots permits rotational grazing, the advantages of which will be discussed later.

Chart A.—Grassland Management Demonstration.
Arrangement of Plots.

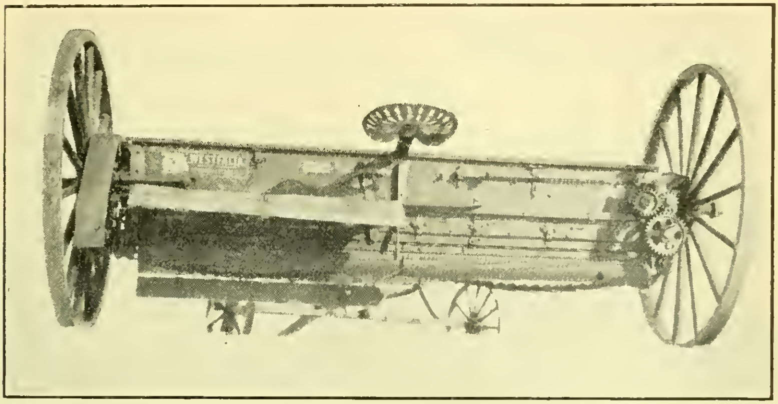


Use of Concentrated Fertilizers

The second principle is fertilization with concentrated fertilizers to provide a luxuriant growth of grass of high nitrogen content. At the beginning of the experiment the land was in a better state of fertility than the average New England pasture, since it had been limed and manured in the previous crop rotations. Early in 1928 all plots except IV received a complete fertilizer and later three additional applications of nitrogen were made during the same season. The fertilizers used were Nitrophoska II and Calurea. Nitrophoska II, a high analysis complete fertilizer containing 16.5 per cent nitrogen, 16.5 per cent phosphoric acid and 20 per cent potash (16.5-16.5-20), was applied at the rate of 334 pounds per acre as soon as it was possible to get on the land in the spring. Calurea, a product containing 34 per cent nitrogen and 13 per cent lime, was applied as a summer top dressing three times during the season at the rate of 30 pounds per acre for each application. The applications of Calurea were made in early June, the middle of July and the latter part of August.

Fig. 1. The Westfalia Fertilizer Distributor.

Note endless chain which feeds the fertilizer from the hopper to the revolving beaters for even distribution.



In 1929, Plot IV again served as a check, and Plot VI received only phosphoric acid and potash. These were applied in the spring in the form of superphosphate at the rate of 258 pounds per acre and muriate of potash at the rate of 100 pounds per acre, thus making the total phosphoric acid and potash on this plot for the season the same as that received by the complete fertilizer plots. It was felt that the phosphoric acid and potash could be reduced the second year. Therefore, in 1929 the remaining plots received a spring application of only 250 pounds per acre of the same complete fertilizer, while the summer top dressing of the nitrogen fertilizer was increased to 44 pounds of Calurea per acre for each of the three applications, which were made at approximately the same dates as in 1928.

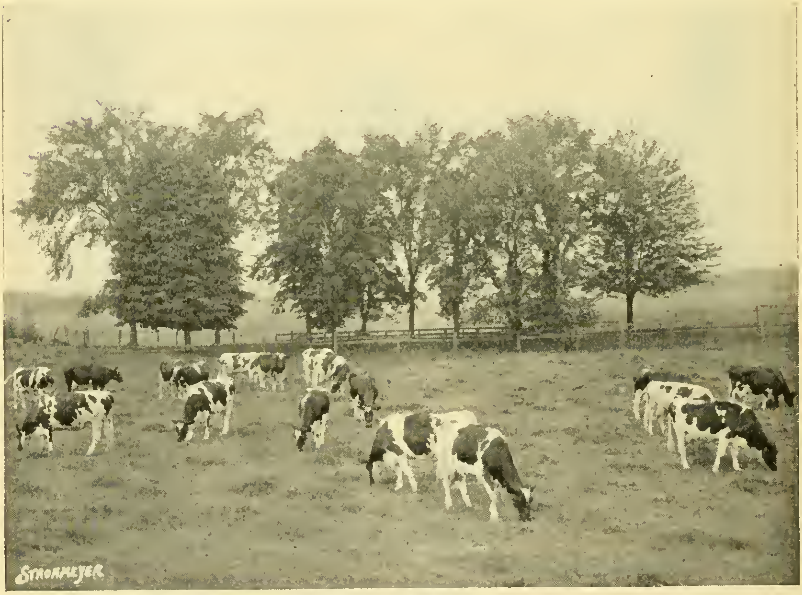
Thus in 1928 a total of 85 pounds of nitrogen, 55 pounds of phosphoric acid and 67 pounds of potash was applied during the season. In 1929 the total application was 85 pounds of nitrogen, 41 pounds of phosphoric acid and 50 pounds of potash per acre. To summarize: Plot IV received no fertilizer treatment, Plot VI received a complete fertilizer in 1928 and phosphoric acid and potash only in 1929, and the remaining plots received a complete fertilizer in both seasons.

Rotational Grazing

The need for rotational grazing and its values are set forth clearly and concisely in the following quotation from an article by J. S. Stewart, Ministry of Agriculture and Fisheries, in the October 1929 issue of "Farm Notes", an English paper published by Nitram Ltd. of London. "Where rotational grazing is practiced, the first grazing should be a light one. Plants must have an opportunity to develop leaf and root, otherwise degeneracy results. Adequate supplies of nutrients and moisture tend to lessen this deterioration, but the more luxuriant leafy species are most seriously weakened and take some time to recover, their place tending to be taken by the more lowly and comparatively worthless grasses and weeds, the complete defoliation of which is more difficult" (because of their lack of palatability). Thus under the old system of unrestricted grazing, the more palatable grasses are weakened by continuous close cropping, while the unpalatable weeds are allowed to grow and reproduce unhindered. Under the new system, the regular rest periods permit the more luxuriant grasses to make an adequate top growth during the recuperating period and to strengthen their root system before being eaten down again.

Fig. 2. Pasture Scene in August, 1927, before the Experiment Began.

Note the uneven appearance of the pasturage.



The college dairy herd consisting of Holsteins, Ayrshires, Guernseys, Jerseys and milking Shorthorns and a part of the college flock of sheep were used for the experiment. In order to make the most efficient use of the pastures, the cattle were divided into three groups: the higher producers (Group 1), the lower producers (Group 2), dry cows and young stock (Group 3). At the beginning of the season the milking herd, which averaged 44.4 head in 1928 and 43.5 head in 1929, was divided into two groups on the basis of milk production. Whenever changes occurred during the season an attempt was made to keep the two groups about the same in number and to keep the higher producing animals in Group 1. The third group averaged 28.6 head for the season of 1928, composed of 27 dry cows and young stock and 1.6 horses; while in 1929 this group was somewhat larger, averaging 33 head of dry cows and young stock and 26 sheep.

Fig. 3. The Same Pasture in May, 1929, the Second Year of the Experiment.

While these two pictures are not absolutely comparable because they were taken at different times of the year, nevertheless anyone familiar with pasture conditions knows that the same irregularities as shown in Figure 2 would have appeared early the next season if the pasture had not been harrowed.

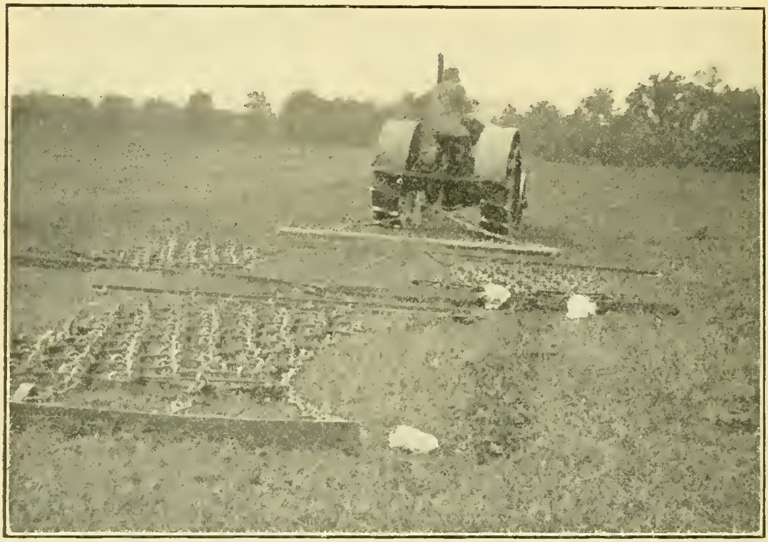
Throughout the season the groups were rotated from plot to plot according to the third principle of the system. Group 1 should show the greatest returns from the best feed; consequently, it was placed first in the rotation and at a time when the grass was about four inches high. After the choicest portion of the pasture had been grazed, these cattle were moved on to the next plot, and their place was taken by Group 2, which in turn was followed by Group 3. The latter group, being on pasture continuously, could still secure abundant feed by closer grazing. After the entire plot had been grazed sufficiently close by the last group, it was given a rest period of about two weeks before the high producers were brought on to it again.

Combination of Grazing and Hay Land

The fourth principle provides for additional pasture during July and August. The first six plots furnished abundant feed for the herd during May and June and were used in rotation, while VII, VIII and IX were allowed to produce a crop of hay. After the hay harvest early in June, these plots furnished additional pasturage needed during the latter part of the season.

Fig. 4. The Fella Harrow Distributing the Droppings.

The three handkerchiefs mark off the area over which a single dropping is distributed. Undisturbed droppings show on the extreme right.



Field Operations

Harrowing

In early spring the plots were gone over with a "Fella" harrow, a German invention, of the chain type, one side of which is intended for use in aerating the soil and breaking up the manure clumps. The other side is used later in the season for distributing the droppings. At the beginning of each rest period, the plot was harrowed with the "Fella" to distribute all droppings evenly in order that they might be used to the best advantage as fertilizer and to prevent the enormous waste otherwise resulting from the refusal of cattle to eat the rank growth of grass around manure clumps.

A striking feature of the experiment has been the even appearance of the grass on the plots throughout the season. It is estimated that the amount of feed spoiled on heavily grazed pasture when droppings are allowed to accumulate would, if conserved, more than cover the cost of harrowing. Assuming, for example, that the droppings per cow per day cover a square yard of good pasture when allowed to remain, then in a pasture season of 150 days, this will mean one hundred and fifty square yards per cow per season. The rank growth around such spots will easily double this area, and in a herd of only twenty cows this would mean a loss of one and a quarter acres of pasture for the season.

Fertilizing

The complete fertilizer in the form of Nitrophoska was applied the latter part of April with a Westfalia fertilizer distributor imported from Germany. This is an endless chain sower equipped with revolving beaters which is designed to spread evenly amounts as low as thirty pounds per acre. The nitrogen fertilizer in the form of Calurea was applied with this machine as a summer top dressing three times during the season at the beginning of the rest period.

Rolling

In the spring, as soon as the plots had dried out sufficiently, they were rolled with a heavy concrete roller to compact the soil and encourage a stronger turf less liable to injury from the tramping of the cattle. In addition to compacting the soil, this operation helped to smooth out the turf on certain areas which had been badly cut up by the cattle during the previous wet season.

Haying

Plots VII, VIII and IX were mowed early in June, yielding a hay of excellent quality, high in protein. By the middle of July these plots were ready to be grazed and were incorporated into the rotation to supplement the first six plots. In 1928 the season was extremely wet and some difficulty was experienced in curing the hay. Consequently the hay remained on the plots from 10 to 22 days and considerable portions of the grass under the windrows were killed out, thus handicapping these plots for the rest of the season. In 1929 the weather was ideal for haying and the hay was put into the barn in fine condition. Plot VIII was mowed rather early, and this fact explains the marked reduction in yield as compared with the previous year. Hay taken from the plots was weighed and representative samples were secured. The moisture content was determined by the chemistry department, and the yield on all plots was computed on a 12 per cent moisture basis. The dry matter was analyzed for nitrogen, and the protein content calculated.

Results of Two Years' Work

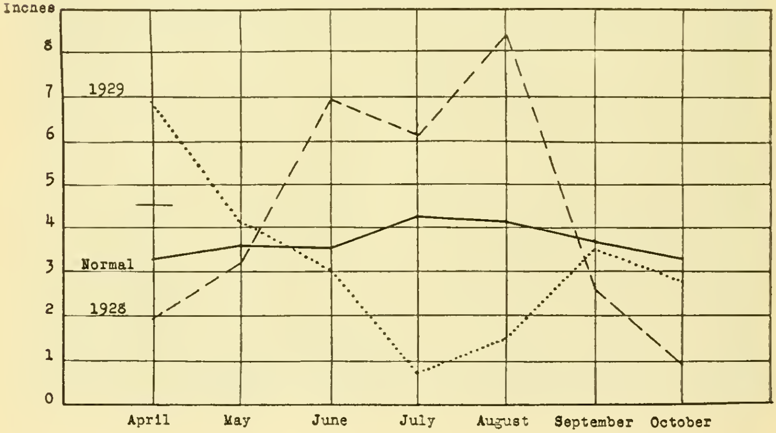
Records were kept throughout both seasons of the weights of the cattle, milk production, additional feed consumed, yields of hay, and costs of all field operations. A daily record was kept for each plot of the number of each class of stock pastured, milk produced and additional feed consumed while on that plot.

Rainfall During the Pasture Season

Chart B presents graphically the monthly rainfall at Amherst during the two years of the experiment and the normal rainfall for the same period. The usual pasture season is about 160 days and extends from early May to the middle of October. The rainfall for the six months period, May 1—October 31, as averaged over the last forty years at the college meteorological station is 22.9 inches. In 1928 the total rainfall for that period amounted to 28.8 inches. It was reasonable to assume that the experiment had probably been unduly favored by this liberal moisture supply. In 1929 the total precipitation for the same period was only 15.8 inches, with 0.7 of an inch in July and 1.5 inches in August. In spite of this prolonged drouth, all plots showed a greater carrying capacity than in 1928, and all plots except the check and plot VI which received no nitrogen in 1929, showed an increased return per acre. This fact is so contrary to the natural expectation under normal untreated pasture conditions that it deserves special attention.

Chart B.—Monthly Rainfall in Inches During the Pasture Season.

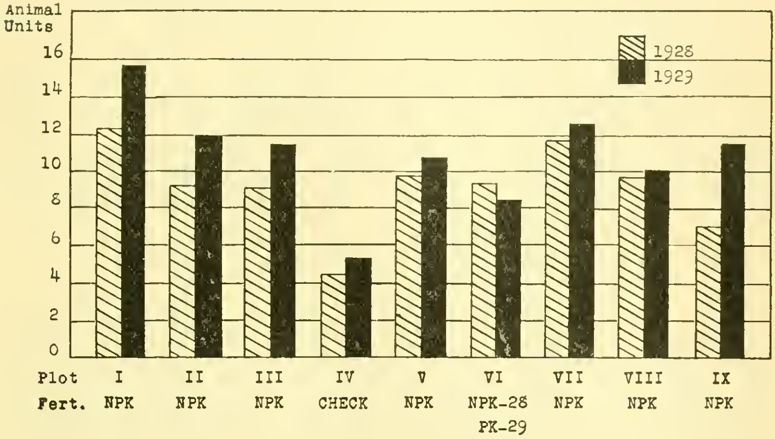
1928 and 1929.



Carrying Capacity of the Plots

The carrying capacity in animal units for each plot during 1928 and 1929 is presented in Chart C. An animal unit was taken as the equivalent of one mature cow, one and one-half heifers, eight ewes or ten lambs. The pasture season was taken as 163 days, and the carrying capacity equals the total pasture days for the plot divided by the days in the pasture season. For example, on this basis Plot I with a carrying capacity of 15.2 would have furnished pasturage for 15 cows during the entire season. It is evident that, with the exception of Plot I which had been in pasture for a longer period and thus had a better pasture turf at the beginning of the experiment, there was but slight variation between the plots (I, II, III, V) which received the complete fertilizer and were grazed the entire season. In order to put all plots on a directly comparable basis, that portion of the grass which was harvested as hay was converted to animal units by taking 25 pounds of hay per day as the equivalent of one animal unit. On this basis Plots VII, VIII and IX ranked well up with the other plots though they were actually grazed only part of the season. The variations shown by Plots VII, VIII and IX in 1928 were apparently in proportion to the amounts of hay damaged by rain and to the turf injury by the cattle. The lower carrying capacity of Plot VIII in 1929, as has been pointed out, was due to the lower hay yield since it was mowed early in June. With the exception of Plot VI which received no nitrogen in 1929, all the fertilized plots showed a greater carrying capacity the second season, probably due to an improved pasture turf and the residual effect of the fertilizer applied the previous season. Even the check plot apparently benefiting from the rotation and field operations showed a slight increase in spite of the dry season.

Chart C.—Carrying Capacity per Plot in Animal Units.
1928 and 1929.



In Table 1 the plots receiving a complete fertilizer were divided into those used primarily for grazing (I, II, III, V) and those which were cut for hay and grazed later in the summer (VII, VIII, IX), and in the following discussion the former are called the "grazed" plots and the latter the "hay" plots. Plot IV, the check, and Plot VI, the PK plot, are treated separately for the two seasons. In 1928 the ratio of milch cow days for the four groupings Plots I, II, III, V; Plot IV; Plot VI and Plots VII, VIII, IX was 11 : 4 : 10 : 4. Thus the average of the grazed plots was approximately the same as Plot VI since in 1928 Plot VI received the complete fertilizer. The grazed plots averaged two and one-half times as many milch cow days as Plot IV, while the hay plots averaged as many milch cow days as the check and in addition produced an average of 1.4 tons of hay per acre. The corresponding ratio for the young stock group is 5 : 3 : 5 : 1.6. The check plot made a better showing here since quality of feed was less important in this group, and the hay plots ranked lower since the feed was used primarily for the milking groups. The second season the complete fertilizer plots, both grazed and hay plots, showed greater capacity, the check plot remained approximately the same, and the ratio on Plot VI was about one-half of the 1928 figure, as follows: 12 : 4 : 5 : 5. Thus Plots I, II, III, V carried the milch cows more than

Table 1—Pasture Season 1928 Compared with 1929.

	Grazed Plots Average of I, II, III, V		Check Plot IV		Plot VI		Hay Plots Average of VII, VIII, IX	
	1928	1929	1928	1929	1928	1929	1928	1929
	NPK	NPK	0	0	NPK	PK	NPK	NPK
Pasture Days in Animal Units—per Acre								
Milch Cows:								
Group 1	70	79	26	22	66	34	28	31
Group 2	67	69	24	24	56	30	23	31
Total	137	148	50	46	122	64	51	62
Group 3:								
Young stock	56	67	36	41	59	65	19	25
Others	4	12	2	9	2	10	1	3
Total	60	79	38	50	61	75	20	28
Total G.1, 2 & 3	197	227	88	97	183	139	71	90
Yield of Hay per Acre—Pounds (12 per cent moisture basis)								
	0	293*	0	61*	0	520*	2789	3206
Milk Produced per Acre (Pounds)								
	3412	3875	1288	1127	3137	1694	1322	1480
Additional Feed per Acre (Pounds)								
Concentrates	1203	984	417	286	1073	409	478	417
Silage	3153	2122	1028	481	2683	817	1597	1048
Beet Pulp	290	216	72	48	272	109	124	85
Hay	206	171	27	37	87	81	49	55

* Plots I to VI were mowed during July to remove grass which had passed the grazing stage. This was weighed and credited to each plot.

three times as long as the check and almost two and one-half times as long as Plot VI and the hay plots. Plot VI and Plots VII, VIII and IX carried the milch cows for approximately the same length of time, but the latter produced an average of one and one-half tons of hay per acre in addition. Both Plot VI and the hay plots were superior to Plot IV. The ratio for Group 3 was very similar to that of 1928, being 6 : 4 : 6 : 2, with the hay plots again lowest since the more succulent feed on these plots during July and August was reserved for the milch cows.

Unfortunately, some of the grasses, particularly on Plots I, II, and VI, passed beyond the grazing stage and as a result, it was decided to mow all six plots and credit the hay to each plot. This explains the hay yield on the plots used primarily for grazing.

The milk production, of course, was almost directly proportional to the milch cow days, being three and one-half times greater on the grazed plots than on the check in 1929, and two and one half times greater on these plots than on Plot VI and the hay plots.

In comparing additional feed, it should be kept in mind that the cows were not on Plots IV and VI early in the season while still receiving additional roughage in the barn or late in the season while being changed over to winter feed, thus giving these two plots an advantage from the standpoint of cost of additional feed. The fertilized plots were ready for grazing earlier in the spring, showed a greater response to the fall rains by increased growth of the grass, and furnished late pasture after Plots IV and VI had been grazed as closely as was advisable.

Milk Production and Returns per Acre

Chart D brings out the close correlation between milk produced and net returns per acre over feed, fertilizer, field and land costs, thus emphasizing the fact that the primary value of this system is for milk production. The graph at the top represents milk produced per acre in pounds, while the lower graph gives the returns per acre over the above costs for the two seasons. The first six plots maintained the relationships shown in Chart C, but the hay plots showed a decided difference. The actual milk production was much lower on these plots than on the other fertilized plots since they were grazed only during the latter part of the season, although converting the yield of hay to pasture days had placed them well up in carrying capacity.

The returns per acre over feed, fertilizer, field and land costs as charted in the lower graph varied directly with the milk production on the various plots, being considerably lower on the hay plots than on the plots used primarily for grazing, and thus demonstrating the advantage to the farmer of letting the cows harvest their own feed as succulent pasture grass instead of hauling it to them in the barn as hay. With the present high cost of labor, this saving may amount to a considerable sum, and in addition the cows utilize the grass in its most palatable and nutritious form. Without question the third group and the hay plots are necessary to the proper functioning of the system as applied at the college, but the system may be so modified as to make them unnecessary. For example on a less extensive scale, the milking herd might

Chart D.—Milk Produced and Returns per Acre.

1928 and 1929.

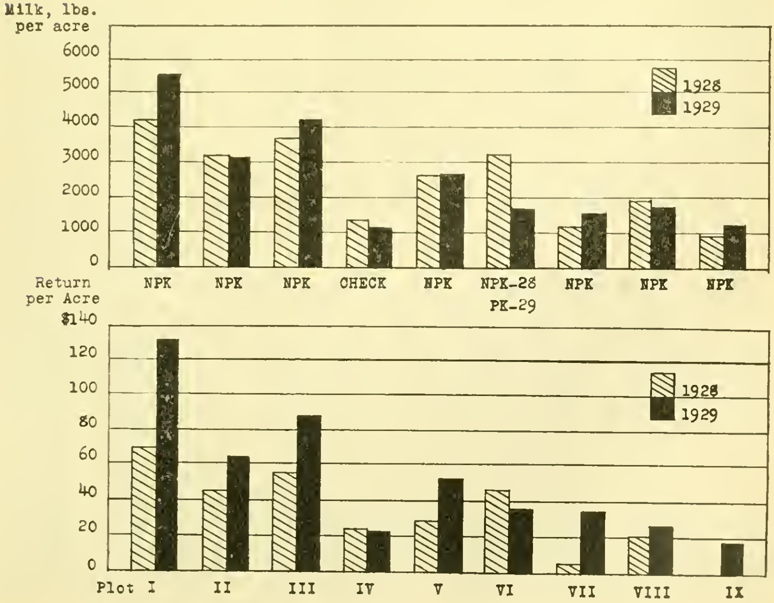


Table 2—Costs in 1928 Compared with 1929.

	Grazed Plots Average of I, II, III, V		Check Plot IV		Plot VI		Hay Plots Average of VII, VIII, IX	
	1928 NPK	1929 NPK	1928 0	1929 0	1928 NPK	1929 PK	1928 NPK	1929 NPK
Costs and Returns per Plot and per Hundredweight of Milk								
Costs:								
Feed	$423.97	$327.46	$135.05	$86.44	$370.44	$139.07	$179.16	$140.72
Fertilizer	174.40	157.45	0.00	0.00	174.40	46.30[1]	174.40	157.45
Field costs	52.88	79.94[2]	36.04	55.53[2]	58.88	60.99	148.57	124.31
Land rental	99.00	99.00	99.00	99.00	99.00	99.00	99.00	99.00
Total Costs	$750.25	$663.85	$270.09	$240.97	$696.72	$345.36	$601.13	$521.48
Credits:								
Pasturage of Group 3 at 7½¢ per head per day	$52.70	$73.90	$33.98	$46.90	$52.87	$70.74	$17.03	$26.44
Yield of hay at $18 per ton	0.00	21.76	0.00	4.50	0.00	38.63	207.11	238.03
Total Credits	$52.70	$95.66	$33.98	$51.40	$52.87	$109.37	$224.14	$264.47
Net costs per plot	$697.55	$568.19	$236.11	$189.57	$643.22	$235.99	$376.99	$257.01
Milk produced (pounds)	28,151	31,969	10,624	9,299	25,881	13,976	10,904	12,216
Sale value of milk per cwt.	$3.95	$3.95	$3.95	$3.95	$3.95	$3.95	$3.95	$3.95
Net costs per cwt. of milk	$2.48	$1.78	$2.22	$2.03	$2.49	$1.69	$3.46	$2.10
Net returns per cwt. of milk	$1.47	$2.17	$1.73	$1.92	$1.46	$2.26	$0.49	$1.85
Net returns per plot	$413.82	$693.73	$183.80	$178.54	$377.86	$315.86	$54.43	$225.99
Costs and Net Returns per Acre								
Fertilizer costs per acre	$21.14	$19.08	$0.00	$0.00	$21.14	$ 5.61	$21.14	$19.08
Other costs per acre	69.80	61.38	32.74	29.21	64.04	36.25	51.72	44.12
Net returns per acre	50.16	84.09	22.28	21.64	45.80	38.29	6.48[3]	27.39

In this table costs include only those costs listed. Barn labor is not included in figuring ''Net Costs'' or ''Net Returns.'' It is recognized that not all of the milk produced or of the ''net returns'' per acre should be credited to the pasture alone, since the supplementary feeding supplied a considerable portion of the nutrients during both seasons. The area of a plot is 8¼ acres.

[1] Superphosphate and muriate of potash.

[2] Higher figures for field costs in 1929 on the first five plots were due to more frequent harrowing and additional haying operations.

[3] Extremely low returns per acre on Plots VII, VIII and IX in 1928 were due to the fact that the hay remained on the plots from 10 to 22 days after cutting, owing to unfavorable weather conditions. These plots were also badly cut up by the cattle during the wet season.

be divided into two groups, fewer plots used in the rotation, and meadowland from which the first crop had been harvested used to supply the necessary late summer supplementary feed. Provision of course must be made to supply the roughage necessary for winter feed.

All the plots which received the complete fertilizer showed a notable increase in returns per acre as compared with 1928. Plots VII, VIII and IX in particular showed greatly increased returns per acre in 1929 due to a larger yield of hay as a result of more favorable haying weather and almost complete recovery of the turf which had been badly damaged the previous wet season. Plot IV, although showing a slightly increased carrying capacity, gave lower returns per acre because of the lower milk production in 1929, while Plot VI also showed decreased returns over feed, fertilizer, field and land costs in 1929.

Table 2 presents a summary and comparison for the two years of all expenditures, covering feed, fertilizer, field costs and land rental, and all credits for pasturage of young stock and yields of hay, but does not include barn labor. All feed was figured at the following prices per ton: Grain, $48; beet pulp, $55; silage, $8; and hay, $18. The retail price delivered was used in calculating fertilizer costs, both Nitrophoska and Calurea being figured at $100 per ton, while superphosphate was charged at $23 and muriate of potash at $53 per ton. Pasturage of young stock was credited at the rate of 7½ cents per animal per day, and hay at $18 per ton. From these data the cost per hundred pounds of milk and the returns per acre over the above costs were calculated and are presented in the table.

In 1928 the unfertilized plot naturally produced a unit of milk most cheaply, with the grazed plots ranking second; but due to the greater quantity of milk produced on the latter, the returns per acre were two and one-half times more on these fertilizer plots, being $22.24 for Plot IV and $59.16 $53.[illegible] for the average of Plots I, II, III, V. Similarly in 1929 the cost per unit of milk was slightly lower on Plot VI than on those receiving a complete fertilizer (grazed plots), but the latter showed double the returns per acre, yielding $84.09 as compared with $38.29 on Plot VI. The return of $38.29 in 1929 on Plot VI as compared with $45.80 in 1928 appears somewhat inconsistent. Based on the experience of 1928, however, the expense of additional barn feeding was greatly reduced on all plots in 1929, thus favoring this plot as compared with the previous year; and unquestionably it benefited by the application of a complete fertilizer in 1928. The higher cost on Plot IV in 1929 is explained by the low milk production on that plot in relation to the value of the land and the cost of field operations.

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The returns per acre above feed, fertilizer, field and land costs, then, are the significant figures in the accompanying table, since naturally an unfertilized plot will produce a unit of milk most cheaply and the addition of each succeeding fertilizer element raises this figure slightly. It is a question not of producing one unit most cheaply, but of producing milk during the pasture season most economically, that is, of making the greatest net returns.

Weights of the Animals

All the animals in the experiment were weighed in order to make sure that the young stock made gains consistent with good live stock management, and that the cows maintained their condition throughout the season. The average figures are shown in Table 3.

Table 3—Weights of Animals.

Group	Number of animals		Average initial weight		Total gain		Average daily gain per head	
	1928	1929	1928	1929	1928	1929	1928	1929
			Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Milch cows	61	63	1152	1133	3904	2040		
Young stock	35	49	686	711	4102	4380	1.0	0.827
Sheep—ewes		42		94		598		.30
Sheep—lambs		31		39		1070		.30

The milch cows more than maintained their weight, the entire herd making a net gain of 3904 in 1928 and 2040 in 1929. During the season of 1929 the milking herd received in addition to pasture an average of 6.5 pounds of grain, 14.5 pounds of silage, 1.4 pounds of beet pulp and 1.08 pounds of hay per cow per day. An average of 25.6 pounds of milk per cow per day was produced. From May 23 to August 2 the cows received no roughage of any kind in the barn and were fed a 14 per cent ration at the average rate of 1 pound of grain to 4½ pounds of milk for all breeds. The young stock group, which was on pasture continuously, received no supplementary feed and averaged a daily gain of 0.827 pounds which was slightly less than in 1928. The sheep did especially well in the experiment as the constant rotation lessened the infection from parasites as well as providing abundant feed. Both ewes and lambs averaged a daily gain of 0.3 pound per head while on pasture; the lambs being on the experimental plots from May 14 to September 6 and making an average gain of 34 pounds per animal.

Analysis of Grass[3]

Throughout the pasture season grass samples were taken from the various plots and analyzed for nitrogen content by the chemistry department. The samples were carefully collected by clipping the grass from six representative areas on each plot the day before the high producing group was turned onto the plot. The six areas, each 2 feet square, were located at certain "staggered" intervals over the plot and the locations were marked on the divison fences. The samples from all plots receiving the complete fertilizer averaged 17.5 per cent protein (calculated) in the dry matter for the two seasons. All samples from the check plot averaged 12.3 per cent protein (calculated), while in 1929 the samples from Plot VI which received only phosphoric acid and potash averaged 15.6 per cent.

The Two Seasons Compared

Increased production and decreased supplementary feed characterized the second year of the pasture experiment. While the average production per cow per day was approximately the same for the two seasons, being 25.1 in 1928 and 25.6 in 1929, and the average number of animals in the milking groups was 44.4 in 1928 and 43.5 in 1929 or about one cow less for the season, the fact that the pasture season was six days longer in 1929 resulted in a total of 114 more milch cow days the second season. If this figure is converted to milk produced by multiplying it by the average production per cow per day (using the 1928 figure since the slightly higher average production in 1929 cannot be attributed directly to the experiment) the second season shows a gain of 2,861 pounds of milk. Favored by almost ideal haying weather during June, the hay crop for the second season was 24,722 pounds greater. It was felt that the cows were given more supplementary feed than was necessary during the first season; therefore this factor was watched more carefully the second year. With the increased carrying capacity of the pastures, the reduction in barn feeding amounted to 34 tons of silage, 8 tons of grain and 2.5 tons of beet pulp. It is expected that the savings will be even greater as familiarity with the management of the intensive system increases, and the cumulative effect of the treatment becomes more apparent.

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[3] The authors gratefully acknowledge the services of Professor J. G. Archibald of the Chemistry Department who made the nitrogen and moisture determinations.

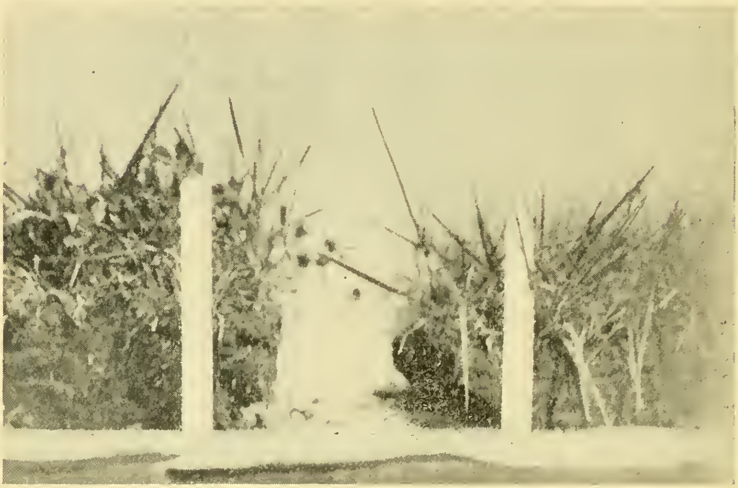
Table 4—Season of 1929 Compared with the Season of 1928

Increased Production:		
2,861 pounds more milk produced	@ $3.95 per cwt.	$113.04
24,722 pounds more hay produced	@ 18.00 per ton	222.55
		$335.59
Decreased Supplementary Feed:		
Roughage:		
67,488 pounds less silage fed	@ $8.00 per ton	$269.95
4,996 pounds less beet pulp	@ 55.00 per ton	136.56
970 pounds less hay	@ 18.00 per ton	8.73
Concentrates:		
15,877 pounds less grain fed	@ 48.00 per ton	378.91
		$794.15
Total Value of Difference		$1129.74

Effect of the System on Vegetation

Some idea of the improvement in the vegetation on the fertilized plots as compared with the check can be obtained from the accompanying picture (Fig. 5) showing representative sod samples from Plot III, which received the complete fertilizer, and Plot IV, the check plot. At the start of the experiment in 1928 the two fields were approximately the same, while the sods shown above were taken in May 1929. A representative area on each plot was selected and the sod to be taken was blocked out by cutting around it with a garden spade. No attempt was made to cut under the sod and when it had been freed on all four sides, it was lifted out taking with it such roots and soil as might be attached. Not only is the white Dutch clover very much in evidence on the fertilized sod, but the height and density of the vegetation on the sod from the fertilized plot is also quite marked as compared with the check. The greater development of the root system on the fertilized sod is evidenced by the difference in the thickness of the soil on the two samples. Thus improved quality and increased quantity of feed along with a stronger turf and a better developed root system may be expected from the application of this system.

Fig. 5. Sods Taken from Plots III and IV, Respectively, in May, the Second Year of the Experiment



Summary and Conclusions

This system of grassland management has been carried on for two years at the Massachusetts Agricultural College and in spite of two extreme seasons, the first wet, the second dry, has shown excellent results. The second year, in the face of a serious drouth, it has shown greater returns and marked improvement in every respect as compared with 1928. The results to date, however, seem to warrant the following conclusions.

1. This system has been practicable even under extreme conditions of rainfall.
2. The carrying capacity of the pastures was greatly increased by the application of the principles involved.
3. The use of concentrated fertilizers improved the quality and increased the quantity of pasture grasses and produced a denser pasture turf.
4. It is evident that nitrogen had an immediate and pronounced effect on the yield of pasturage.
5. It is evident, not only in the data obtained but also as a result of pasture observations, that the beneficial cumulative effects of fertilizer are a factor of outstanding importance.
6. This two year trial has proven that the grazing season may be lengthened and the carrying capacity of a pasture increased by the application of the four principles of this intensive system of grassland management, thus lessening the amount of barn feeding necessary.
7. Because of the difficulty of measuring the many variants involved, definite conclusions regarding management are not possible until the study has been in progress for a period of years. This demonstration is therefore being continued.

Publication of this document approved by the
Commission on Administration and Finance

5 m-3-'30. No. 8225

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 263 April, 1930

Food Service in Massachusetts Rural Elementary Schools

By Esther Davies

Knowledge of the amount and kinds of food service available to the pupils in the elementary schools is a necessary basis for further study of the conditions affecting the health of children from six to sixteen years of age. Since such health studies are contemplated for certain districts of rural Massachusetts, and because information regarding the present practices of the schools in food service was not available, the survey here reported was made during the years 1927-1928 and 1928-1929.

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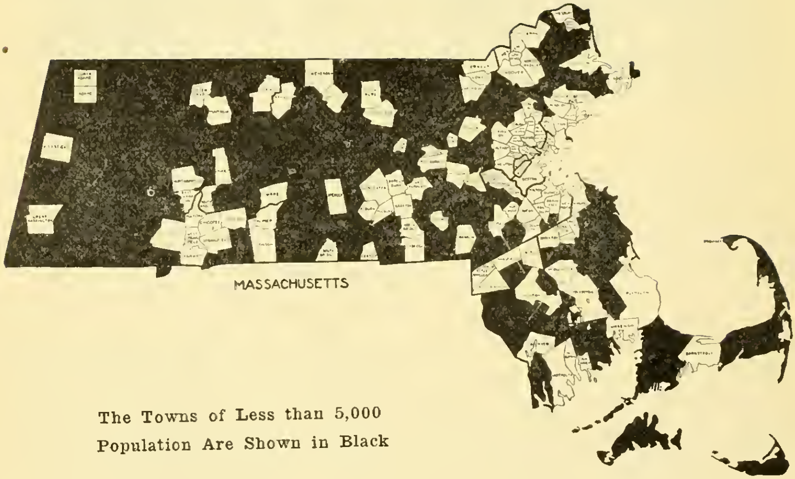
AMHERST, MASS.


MASSACHUSETTS

The Towns of Less than 5,000
Population Are Shown in Black

FOOD SERVICE IN MASSACHUSETTS RURAL ELEMENTARY SCHOOLS

By Esther Davies[1]

In Charge of Home Economics Research

The Scope of the Study

The 236 towns of less than 5,000 population which make up rural Massachusetts have over 66,000 children enrolled in their elementary schools. With 10 per cent of the total state population, these towns have 11 per cent of the elementary school enrollment. In every 1,000 inhabitants there are 164 grade school pupils.

During the years 1927-1928 and 1928-1929 members of the staff of the Department of Home Economics Research visited the schools of 155 of these towns, to study the arrangements for food service and their relation to the health of the pupils; for it was believed that conditions would differ radically from those which had previously been found to exist in city school systems, and that the problems of food service in the rural schools might be more difficult than those of the larger communities. Through correspondence with the school superintendents, enough information was obtained for 67 more towns to warrant their inclusion in this study; giving a total of 222 towns, with an elementary school enrollment of 57,600 pupils, as the basis of this report. The geographic distribution of the towns is shown by the accompanying map. (A New England town, it should be remembered, is comparable to what elsewhere in the United States is called a township.)

The scattering of the rural school children in a large number of small and frequently isolated buildings greatly increases the per capita cost of providing adequate equipment for lunch rooms or any other type of food service; and the largest consolidated school in any of these towns is a comparatively small unit. In a discussion of the defects in the practices of the rural schools it should always be borne in mind that the burden of financing the school system is proportionately heavier in the country than in the more populous centers, and they must be criticized from the point of view of what improvements might be made without appreciable added expense rather than by comparison with an ideal based on a large budget allowance.

The 57,600 pupils of the 222 rural Massachusetts towns are housed in 800 school buildings, of which 370 (46 per cent) are one-room, one-teacher buildings; 208 (26 per cent) have two or three rooms; and the remaining 222 (28 per cent), four or more rooms. It is evident that, in spite of Massachusetts' history as the first state in the Union to establish a consolidated school, the one-teacher building, with from four to eight grades, is still frequently found in the Commonwealth. However, what may be termed partial consolidation has taken place to a great extent. Instead of six or eight or ten one-room buildings per town there are now likely to be one or two larger schoolhouses, with only a few of the one-room type left. In 28 of the 222 towns complete consolidation has taken place, so that all the elementary school pupils attend one building. On the other hand, 20 towns have no building larger than the one-room, one-teacher schoolhouse. In the remaining 174 towns there is partial consolidation.

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[1] The author wishes to acknowledge the help of Cornelia B. Church, Laboratory Assistant in Home Economics Research, by whom part of the field work of the study was done.

Among all these rural towns, consolidation has progressed to the extent that over 15,000 pupils, or 28 per cent of the total enrollment of the grades, attend schools so far from their homes that the school authorities are by law obliged to provide transportation. In addition to these 15,000 children for whom transportation is furnished (and who, of course, cannot go home at noon), approximately 1,000 children who walk to school in the morning bring their lunches because the distance is too great to permit returning home for lunch. There are, therefore, 16,000 pupils who must remain at the schoolhouses during the noon recess, and who constitute the problem of noon food service.

The schools in 109 of the rural towns have no food service whatsoever; in 60 towns, some service exists in part of the buildings; while in only 53 towns (including the 28 having one building each) is there service of any kind in every schoolhouse. A fairer and more significant unit for the study of school food services, however, is the building. As said above, in 60 towns the fact that one building makes provision for a food service has not led to the establishment of the service in all the other buildings; and a service in a school at one end of a town is of no benefit to children going to buildings in other sections. The reason for this lack of uniformity in the practice in the various buildings of any one town will be discussed later.

Taking the building as the unit, it is found that in 567 (71 per cent) of the 800 buildings there is no food service of any sort at any time during the school year. Over 6,000 of the children who attend these schools without any food service must remain through the noon hour during all the year, and more stay when the weather is severe.

The amounts and the kinds of food service in the buildings of the 222 towns are shown in the following tabulation:

Type of food service	Number of buildings	*Per cent of total buildings*
None	567	*71*
Hot drink or soup, during winter only	185	*23*
Meal, entire school year	23	*3*
Milk only, entire school year	25	*3*
	800	100

In 13 of the 25 buildings having milk service only, it is a mid-morning service; in 12, a noon service.

There is no uniform relation discoverable between the availability of a service to the pupils and its popularity. As will be seen in the discussion of the lunch rooms where food is served (page 61), the proportion of pupils taking advantage of the opportunity varies widely; with the attitude of the teachers, the success of the management in serving palatable food at low cost, and the willingness of the parents to provide money, as well as, at times, the proximity of a hot dog stand. In general, in the isolated one-room school the service is better patronized than in the larger buildings situated in villages, even though these latter may have a higher proportion of children staying for the noon meal. This is primarily due to the teacher's efforts; for if the lone teacher is willing to undertake the labor involved in any kind of service, she is sufficiently interested to make the children enthusiastic supporters of the project; while in bigger buildings, where a specially employed person runs the service, there is frequently much indifference on the part of the teachers.

The Need for School Supervision of the Children's Food

The propriety of considering pupils' food a matter within the province of school authorities and teachers is justified by a study of (1) the number of absences due to digestive disorders; (2) the contents of the children's box lunches; and (3) the inability of the individual pupil to provide, without co-operation, certain highly desirable types of food and food service. Furthermore, a lunch period supervised both as to nutrition and as to conduct offers unusual opportunities for education in health and training in essential good manners.

Nutrition

That frequently there remains much to be desired in the nutrition of the elementary school child is evident from a scrutiny of the real causes of absence from school. During the year 1928-1929, 16 teachers of schools in various parts of the state kept for this study special records of the number, duration, and true cause (not necessarily the reason appearing on the child's excuse) of all absences. Of the 470 children included in the records, 213 walked to and from school and 257 were furnished transportation. Second only to colds among the illnesses were "stomach upsets", and many of the absences tabulated under the heading of "colds" were recorded by the teachers as "indigestion and cold". The absences due to digestive disturbances were proportionately more frequent among the children who rode to school than among those who walked. All the children who rode ate lunch at school, while almost without exception those who walked lived near enough to go home for the noon meal. A factor in the greater incidence of indigestion among the children who ate box lunches may be the "piecing" habit of these children. It is rare to find a child bringing food to school if he is going home at noon, while it is even more rare to find one who has a lunch box who does not eat from it at recess—generally a large portion of cake. This practice is by no means the same thing as the serving of a carefully chosen mid-morning lunch. It might be stopped by the teachers, but they do not very often attempt to do so.

To ascertain with definiteness and detail just what the children really do carry to school in their lunch boxes, the following procedure was used. A school was visited in the morning and, with the consent of the teacher, each pupil asked to bring his lunch box to his desk and then write down, item by item, exactly what it contained. To insure accurate reporting, the teacher supervised the work and if necessary helped the smaller pupils with the writing. Data on 1,560 lunch boxes were thus secured from the schools of 34 towns and the principal items have been tabulated, as shown on page 56 and in the chart on page 57. These include lunches carried by children from all the eight grades of the elementary schools.

Another tabulation, made to see whether or not the lunches of the younger pupils varied to any marked degree from those of the older ones, brought out only one difference—a tendency on the part of the smaller children to take milk or cocoa more frequently than do the pupils in the upper grades. This may be because the parents do not see as much necessity for urging milk consumption by the children beyond the third grade as by the younger ones; or it may be on account of the dislike of the children for carrying such foods, which dislike is asserted more as they grow older.

Principal Items in Box Lunches

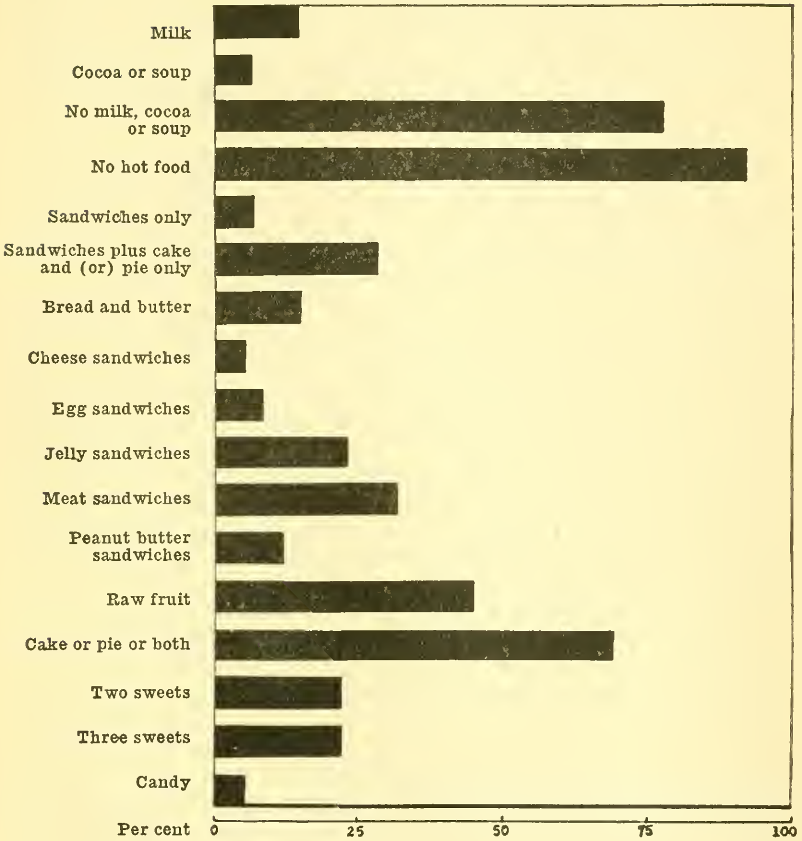
Food	Number of lunches	*Per cent*
Milk	234	*15*
Cocoa or soup	109	*7*
No milk, cocoa or soup	1,217	*78*
No hot food	1,448	*93*
Sandwiches only	119	*8*
Sandwiches plus cake and (or) pie only	458	*29*
Sandwiches: bread and butter ([1])	248	*16*
cheese	92	*6*
egg	147	*9*
jelly or jam	374	*24*
meat ([2])	513	*33*
peanut butter	192	*12*
Raw fruit	708	*45*
Cake or pie or both	1,077	*69*
Two sweets	349	*22*
Three or more sweets	351	*22*
Candy	88	*6*
Total number of lunches	1,560	

[1] Includes all butter substitutes.

[2] Includes fish, as salmon, sardine, etc.

The item "cake and (or) pie" includes cake, doughnuts, and very sweet, fancy crackers, as well as all sorts of pie. These are the foods which are chiefly responsible for the presence of two sweets in 22 per cent of the lunch boxes and three or more sweets in 22 per cent more; a total of 44 per cent of the lunches, therefore, containing two or more sweets. Candy, it will be noted, did not appear in many of the lunches. Like ice cream it is eaten frequently, and in large amounts, by many children if there happens to be near the school building any place where it can be bought.

The raw fruit reported as a constituent of 45 per cent of the lunches is almost without exception apples. Most of the original data regarding these lunches were collected during the months of December, January, February, and the early part of March. It would seem true, from the contents of those lunches seen in April and May, that had all the data been secured later in the school year, when the home stores of fruit are depleted, probably a much smaller proportion of the lunches would have contained raw fruit.


Principal Items in 1,560 Box Lunches

Samples of the menus of the lunch boxes, selected at random, are given below. Quite aside from all questions of nutrition, there was much of interest in the 1,560 lunches as they were recorded by the children. They produced an even one hundred different varieties of spelling the word "sandwich", and several other words had approximately as many variations.

Age of Child	Menu
Nine	Three white bread and jam sandwiches Cake
Eleven	White bread and jelly sandwich Soda crackers Cake Cocoa
Twelve	Four egg salad sandwiches Apple
Thirteen	Two jelly buns (nothing else)
Thirteen	Five ham sandwiches Blackberry pie Cake Apple Orange
Thirteen	Two ham sandwiches Jelly doughnut Cake Pickle Maple sugar

It is evident from this study of what the children actually do carry to school that it is very unusual to find anything hot included in the lunch. This is one of the outstanding lacks of the box lunch, and constitutes a problem which can be most successfully solved by a school food service. Moreover, the co-operation needed to run the food service, particularly in the smaller schools, is a step towards the educational goal of the supervised lunch hour.

Education

There are many factors which influence well-being and are involved in the achievement of optimal health by any individual. Yet this does not lessen the importance of any one; and sleep, rest, play, sunshine, fresh air, pure water, as well as clean, suitable food are all essential to a child's present health and future welfare.

Play, sunshine, and fresh air are available to most, if not all of the pupils of the elementary schools of rural Massachusetts, although the supply of fresh air in the schoolrooms could frequently be increased with advantage. In many schools a considerable amount of out-door playtime is given to the children at the rather long morning and afternoon recess periods. At the smaller buildings schedules are somewhat flexible, and lengthened periods on pleasant days may alternate with briefer recesses when the weather is stormy or very cold. Sleep and rest many of the children undoubtedly do not have in adequate amounts; and the purity of the water supply is sometimes open to question. The individual teacher, however, is seldom in a position to alter the situation regarding these.

In almost every rural town in Massachusetts a teacher is required to stay at the school building during the entire noon hour, and whenever there are pupils lunching at the schoolhouse she has an excellent opportunity for elementary lessons in nutrition and the inculcation of those manners and courtesies about eating which are of lasting help to every child. Whether or not such teaching ought to be done in the home rather than in the school is not the question here; the fact remains that even the briefest survey of the eating habits of the children gives conclusive evidence that many have not acquired proper habits. Training in anything as essential as the establishment of a proper attitude towards food because of its important rôle in securing health and happiness for the individual is certainly as legitimate a part of the school's task as is education in the more traditional school subjects.

One of the first things that may be taught in a lunch period is cleanliness, of food, utensils, and hands. Simple procedures, such as the use of pieces of oil cloth or paper napkins, implant the idea that food is something to be kept clean. If, incidentally, the desks are also kept clean, that is an added advantage. Clean hands should not be a problem in a building with running water or even merely a pump. Ingenuity is required to achieve them if the schoolhouse has no water supply other than that in a pail. Here paper towels will be the remedy, for each child may be taught to dip a towel into the pail and wet it sufficiently to make it an efficient tool for cleaning his hands without directly touching the water supply. In this way an entire class may have reasonably clean hands for the lunch periods. Such procedures may seem too obvious and elementary to need mention, but there are unfortunately more schools where they are not practiced than where they are the custom.

Attention may be given to the choice of foods. If there is a food service the teacher is often in a position of authority regarding what is served, especially in the small buildings where the teachers directly supervise or actually do the work. If there is no food service, needed reforms in the contents of the lunch boxes can be brought about gradually. Even the smallest child can be taught a few of the principles of good nutrition; why food is important and why some kinds are particularly valuable for growing boys and girls. It must be remembered that in a great many homes the choice of what goes into the lunch box is left to the child. Even if the lunch is nutritionally very poor, the teacher can control the speed with which it is consumed and also the order in which the foods are eaten, so no youngster bolts cake or pie first and then omits the sandwich. Neither should a pupil be allowed to throw food at his fellows or scatter it promiscuously about the premises, as is now all too often the case.

The supervision of the lunch hour will insure some deliberation in eating. If all the pupils must remain at least 15 or 20 minutes before they are permitted to go onto the playground, the habit of consuming lunch in three or four minutes is broken. The best managed lunch hours seen were those where the children were required to spend a fixed minimum amount of time at lunch. This of itself is conducive to sociability and to learning that a meal eaten with others should have some degree of formality. If the classroom becomes a friendly dining room with the teacher or an older pupil as hostess, talking and pleasantness without boisterousness can be encouraged. Through supervision of the lunch hour the children may be taught much about what to eat and how to eat it. There are in rural Massachusetts some schools where it is most successfully done.

Methods of Food Service in Use

Management—personnel

In 176 (80 per cent) of the 220 buildings which have a noon food service of some sort, it is both sponsored and managed by the teachers, with no help except that of their pupils, and many times without any appreciation on the part of school authorities or parents. In 15 buildings, all of which have both elementary and high school pupils, the management of the food service is one of the duties of the high school teacher of home economics. The school committees of nine towns employ a woman specially to manage the food service and do the work involved. Sometimes her menus are supervised; sometimes not; and the service is for only one building in each of the nine towns. In two buildings (one in each of two towns) the lunch room has been let as a concession, and there is no supervision of the food served. The school nurse of one town sponsors the service in each of three buildings, while the teachers attend to the work. The 4-H club girls in two buildings manage the serving of hot drinks or soup, with the help of the teacher. In the remaining 13 of the 220 buildings with noon food service the work is done by teachers and pupils, while the following organizations help financially: Grange, two buildings, one in each of two towns; American Legion, one building; Parent-Teacher Association, seven buildings, two in one town and five in another; Red Cross, one building; Woman's Club, two buildings, one in each of two towns.

Management—financial

Financially, the most elementary method of managing a school lunch is to have each child provide his own food supplies. Such a plan may be worked out so that it results in suitable hot food for each pupil (see page 62), but it always has the disadvantage of imposing on the small children the burden of carrying containers to and from school. This objection also holds true for the thermos bottle, which when filled is an appreciable weight. The younger pupils' hands are small, and it is often difficult for them to carry containers with food any great distance, especially in cold weather. It is better to devise some way whereby the children do not need to transport daily much food or any heavy containers.

In some schools—for example see page 61—the pupils take turns in furnishing supplies, and then a hot drink or dish in which all share is prepared by the teacher or the older pupils. Such a plan permits a variety of hot dishes without asking a large contribution from any one child. The common hot dish at noon also promotes a feeling of equality and sociability. Frequently each pupil brings from home at the beginning of the school year a cup or a bowl and a spoon, so no money is required for such equipment.

A variation of the above scheme is found in the schools where the children pay small sums of money weekly, in lieu of supplies, and the teacher does the buying for the group. Sometimes the two methods are combined, the children furnishing certain supplies and paying smaller sums of money. All these plans work better in small schools than in those where the enrollment is large enough to make the labor of preparing food so great as to interfere with the other school work. Nevertheless, any one of them could be made to work well in any of the 370 one-room buildings in the rural towns, for the enrollment in a one-teacher school is never large.

In 13 buildings the food service is subsidized by an outside organization. While this may perhaps be a legitimate way to get a food service started, the aim should always be the assumption of responsibility by teacher or school authorities. It is only when the food service is an integral part of the school system that it functions regularly year after year, and the educational opportunities to be found in a supervised food service justify the assumption of responsibility by the schools. In making a survey such as the one here reported, the comment is often heard that "such and such organization used to furnish hot cocoa, but after a couple of years the women got tired of bothering with it"; and that school now has no service. There is little place in school food services for the more or less haphazard management of any Lady Bountiful, be it individual or group. This should not be taken to mean that contributions of money, given to the teacher in order that she may buy food or supplies for those children so very poor that they cannot share in the activities of the other pupils, are in any sense undesirable. Nor is the giving of funds, through the school authorities, to be discouraged. It is the attempt at regular, long-time management of a school food service by an outside organization which too often proves to be spasmodic and of short duration.

The financing of a food service is relatively simple in those few schools where the lunch room is managed by the high school home economics teacher as part of her regular routine. In the smaller of such places the food supplies are usually purchased along with those for the cooking laboratory and no separate accounts kept. The money from sales of food is turned into the general home economics fund and in some schools the teacher is unable to tell whether the lunch service is run at profit or at loss. In the larger schools, separate accounts are kept for the lunch room, but no distinction is made between the service for high school pupils and that for the elementary grades. Although the two sets of pupils usually eat at different hours, there was only one lunch service seen (page 66) where any difference was made in the type of food served.

When a woman is employed especially to manage the food service, she may be expected (1) to charge just enough to cover the cost of food, her salary and other overhead being paid by the school committee; or (2) to make sufficient profit to pay her own wages as well as meet the cost of food supplies. No school was found in which the selling price of food was expected to be high enough to make a profit out of which to buy permanent equipment or to pay for fuel; not even when the lunch room service was run as an unsupervised concession. The school committee may legally spend funds for permanent equipment such as stoves, dishes, tables, and for most of the larger lunch services these supplies had originally been purchased from school funds. The larger schools have been more fortunate in securing equipment than have the isolated, small buildings.

An idea of the foods served, the methods of financing, and the equipment in different types of school can be given most vividly through description of existing services. Many of the better features of these could advantageously be adapted to the needs of the 567 buildings now without food service of any kind.

Types of service

1. The one-room school. Schoolhouse A is a one-room, one-teacher building, with 20 pupils in eight grades. It is located in the country and is without conveniences of any sort. As there is no running water in the building, pails are used for the water supply, the children filling them at the well of a nearby house. The one stove is flat-topped and therefore can be used for simple cooking. At the beginning of the school year each pupil brought from home a large cup or mug and a spoon, and these are kept in a cupboard improvised from a packing box. The equipment for cooking—two large sauce pans, a pail, a couple of big spoons, a paring knife, and some half-worn towels—was contributed by the parents of the pupils from their household supplies.

The pupils, acting on the suggestion and with the supervision of the teacher, divided themselves into four committees of five, each group having both older and younger children. These committees, in turn, plan one hot dish for each day of one week. During the first of the year, the teacher furnished most of the ideas and recipes and gave the work considerable attention, but after a few weeks the children were able to assume most of the responsibility. The committees meet at the afternoon recess to do the planning. When it is a committee's week for the food service, the members devote to the work of food preparation ten minutes before school opens plus the first twenty minutes of the morning session; and at the noon hour help the teacher serve whatever has been prepared. Almost all food supplies are contributed by the pupils. Every committee assigns, for each day of its week, the food to be brought by the pupils. Such a spirit of co-operation has been fostered that it is rare for a child to neglect his share. For the smallest children, the committee generally writes out directions to be taken home. Nothing expensive and nothing not ordinarily kept in every household is ever asked for.

On the day of one visit such assignments as these were made: four carrots; three potatoes; one potato (to be brought by the youngest child); one onion; three slices of bacon; two turnips; one parsnip. All the vegetables, it was specified, were to be brought clean. Out of ingredients like these a vegetable stew was made the next day. Twenty minutes after school started it was simmering in a pan on the heating stove and needed no further attention except occasional stirring. Another day, the teacher had borrowed a large double boiler—loaned for just the one day—and the children had hot rice and milk.

About once a month a five-cent collection is taken, and the teacher invests the money in special supplies not easily brought from the homes.

Each child is responsible for cleaning his own eating utensils. The older boys carry enough water for the dishwashing and an extra pan on the stove provides some hot water. In a building like this one, the hot food service is necessarily restricted to the days on which the heating stove is used, for there is no other way of having heat for cooking.

2. *Buildings of more than one room, but without lunch room facilities.* In Schoolhouse B there are two rooms, with two teachers; one for the first four grades and the other for grades 5 to 8. During the year this building was visited there was a difference of opinion between the teachers as to the desirability of a supervised lunch period, with hot food when possible, and in the upper room there was no attempt at any food service. This teacher did not wish to make the effort required, and discouraged the children from attempting anything. On the other hand, the teacher of the smaller pupils felt that her experience had demonstrated to her satisfaction that a well-ordered lunch hour was worth all the work it might entail.

The building has cold running water; aside from this there is no equipment for food service. Each room is heated by a stove so high and round that it has no surface available for cooking; only a small ledge where a little water could be warmed. The teacher told the investigator that the only food she had been able to cook was baked potatoes; that the children liked these so much that nearly every day the stove was used for heating each pupil brought a potato to be cooked. The sole regulation was that the potatoes must be washed before they were brought to school.

The teacher had obtained a grating which had been put into the stove, above the coals, and on this the potatoes were placed long enough before the noon hour to insure thorough baking. Except for the saucers or plates which the children had for individual use, there was no equipment other than a long-handled fork belonging to the teacher. The regularity with which the pupils brought the potatoes bore testimony to the popularity of this addition to otherwise cold lunches.

Schoolhouse C has found its solution of the problem of hot food in the utilization of a wash boiler. There is only one school building in the town, with four rooms, four teachers, and 120 pupils in the eight grades, 50 of them living so far away that they must remain at the schoolhouse during the noon hour. The building has running water, but no space or equipment for a lunch room. On the advice of the school nurse, the plan in use was worked out, and word sent to all the parents that any food the children brought to school in pint or half-pint covered glass jars would be heated for them; and a suggestive list of suitable foods was added to the mimeographed sheet given each pupil to take home.

The three-burner oil stove, slightly battered yet still efficient, was donated by a friend of the school when it was discarded to make room for a new one. The wash boiler was acquired in the same way. To the question of the investigator about finances, the principal of the building said that the school committee had voted ten dollars for the purchase of fuel. As is so often the case, the school authorities did not believe there was any advantage in having hot food except during the winter months, and the service was only from the first of January to the first of April.

The equipment had been set up in a corridor of the schoolhouse, and the procedure followed was simple. Upon entering the building in the morning, each pupil placed his jar of food on the floor beside the stove. At recess two of the older boys lifted the boiler onto the stove, put a little water into it, adjusted the rack which kept the glass from breaking, and stacked the jars carefully. Later, one of the teachers left her class long enough to light the stove, and just before noon another teacher or an older pupil turned off the fire. At the lunch hour the children filed past, selected their own jars, and carried them back to the school rooms, where each pupil ate at his own desk. Spoons and jars were taken home daily, and no dishwashing was done at the school building.

On one day, a list of the foods found in the 50 jars heating in the boiler included: lamb stew, clam chowder, tomato soup, beef stew, Indian pudding, vegetable soup, peas, creamed potatoes, cocoa; and two jars of apple sauce for children who liked it hot.

The plan has the advantages of almost no work for teacher or pupils at the schoolhouse; little or no extra expense to the families; and chance for considerable variety in the hot dish which supplements the rest of the food which the children bring for lunch. It has the disadvantage of requiring the children to transport food and containers and possibly offers less educational opportunity than a hot dish shared by all alike. It is, nevertheless, the simplest solution for the building without facilities for food service.

A third method of obtaining hot food in buildings with no space or equipment is found in Schoolhouse D. This is a four-room, four-teacher building, with 150 pupils in the first six grades. As the building is located at the center of the village where most of the children live, all except a few go home at noon. For the 15 or so who remain, several years ago the teachers began serving one hot dish daily throughout the greater part of the school year. At the beginning, the dishes and all other equipment were loaned by the teachers; later the school committee purchased a supply of dishes and an electric hot plate. The supplies are kept in the primary room, and the food is prepared there each morning between half past eleven and twelve, after the pupils of that room have been dismissed. Two fifth or sixth grade girls are assigned, weekly, to the task of helping the primary teacher get the food ready and to wash the dishes. For this, they receive food free during their week of work.

This school is one of the few having a mid-morning milk service, and milk is also always available at noon. On the day of the visit, the hot dish was spaghetti and tomatoes. The pupils pay for the food each day: 10 cents without milk and 13 cents with milk. Charge accounts are discouraged, although sometimes permitted. Generally each child has the money ready when he comes for his hot food. The pupils also bring lunch boxes, for there is neither time nor space to permit expansion into meal service. Nearly all the pupils who stay at noon patronize the service regularly.

Here, except for the help the two older girls give, all responsibility is shouldered by the primary teacher. She decides what shall be served, does all the marketing, collects the money, and pays the bills. Without her willingness thus to increase her work this smoothly-running service would not exist. She told the investigator that she had her reward in the improved dispositions and conduct of the children throughout the afternoon session of school.

3. Buildings of more than one room, with some lunch room facilities. Schoolhouse E has been chosen as an example of supplementary food service in larger buildings with some lunch room equipment and a special employee to do the work. This building, located in the village, has 220 pupils in eight grades, with seven rooms and seven teachers. From 75 to 80 pupils are furnished transportation and always remain over the noon hour; in the winter 10 to 15 more children often stay.

The food service is sponsored by the school committee, and the wages of the woman managing it are paid out of school funds. She is expected to charge enough for the food to cover the full cost of food supplies. Equipment and fuel are bought by the school committee. The service is run from November to April.

The cooking is done in a gloomy corner which has been partitioned off the basement. There is no lunch room and the children eat in the class rooms. The manager puts the individual dishes of food on trays, and two pupils from each room are sent down to carry them up and distribute the food to the pupils who have ordered it. Orders are taken by the teachers and the number reported to the manager at the morning recess, when she comes to the building to begin the work of food preparation. The serving is carelessly done, and the food is so often spilled that its appearance is very unpleasing by the time it reaches the consumer. This, along with the monotonous menu, is probably why only one-half of the children remaining at noon patronize the service.

There are always three things available and for more than four winters exactly the same three things: milk, sold for three cents a glass (not bottle); cocoa, also three cents; and one brand of canned vegetable soup, at four cents a bowl. In view of the numerous kinds of canned soup on the market, is would seem quite unnecessary never to have any variation in the sort served. A soup as highly flavored as the one selected for this constant use will after a few weeks cease to appeal. The cocoa did not sell very well, and the investigator believed that the difficulty lay to a great extent in the choice of recipe; the product was too strong of cocoa and too sweet. This is a criticism which applies equally well to the cocoa served in a number of other schools in the state.

This service in Schoolhouse E is one which fails to be of any educational value and which reaches only one-half of its possible patrons; because of untidiness of service, complete lack of imagination in planning the menu, and no supervision and little co-operation on the part of the teachers; not because of the absence of financial support by the school committee.

4. Buildings with meal service. A few years ago the high school teachers of the town in which Schoolhouse F is located each contributed ten dollars towards the establishment of a lunch room service for the high school pupils and also those of an elementary school building across the the street from the high school. The service is now self-supporting so far as food supplies are concerned, and the school committee buys the permanent equipment and also pays the wages of a woman and a helper who together do all the work. The manager has entire charge of making the menus, setting prices, and otherwise determining what the arrangements of the food service shall be. She has had no training in food selection.

About two-thirds of the children in the elementary school who remain at noon patronize the lunch room. They come over to the high school building under the escort of their own teachers and behavior is generally excellent. Elementary and high school pupils do not come to the lunch room at the same time.

Strips of ticket coupons are on sale and the children buy them as they wish, in amounts running from five to fifty cents. The day of the visit, about half the pupils bought tickets as they started along the serving line; the others were already provided. The room itself is a light and pleasant half-basement, and it is kept clean. The food is all excellently prepared and is good of its kind. Whether or not it is the best to set before school children is another matter. There is no supervision of the choices the pupils make. On entering the serving line, they see first of all an array of tempting desserts. These they may themselves place on their trays, while other foods must be specifically requested from the woman who does the counter serving. The day the menu given below was servd, only 36 half-pint bottles of milk had been provided for the 200 pupils (high school and elementary) who would be served; and these few bottles were all out of sight, behind the counter, so that the idea of choosing milk was not suggested to the children. This free choice of food, with desserts most prominently displayed, led one boy of eleven years to buy for his lunch four dishes of coffee-nut-raisin tapioca with whipped cream, and nothing else. No attempt was made to limit purchases to one dessert per pupil or to make the buying of milk or soup or a hot dish the necessary prerequisite to the buying of a sweet. Of the foods available twice as many desserts were sold as were portions of the other foods.

Menu	Cost
Creamed salmon and peas	10 cents
Chicken soup	5 cents
Vegetable soup	5 cents
Sandwiches	5 cents
Milk	5 cents
Coffee-nut-raisin tapioca with whipped cream	5 cents
Chocolate blanc mange with whipped cream	5 cents

A little thought as to the order in which the foods were brought to the pupils' notice, some way of making it easier for them to choose hot food or milk, and less stress on the desirability of sweets, would have done much to improve this lunch room. Here it might be wise to have the same rule as that of the lunch room in Schoolhouse G—that no child may buy dessert only. It would also be well to have the desserts themselves more simple and better adapted to the digestive powers of the children.

All decisions regarding a food service should not be left to the judgment of an employee chosen without reference to her knowledge of nutrition and health, and it is the part of wisdom to make certain that some one directly connected with the educational system—the school nurse or a teacher—gives enough supervision to the lunch room to insure the serving of suitable as well as palatable food.

The lunch room of Schoolhouse G has the best equipment seen in any of the Massachusetts towns of less than 5,000 population. The town in which it is located is comparatively wealthy and has been generous with funds for school purposes. Even in this town, though, there were four buildings without any food service. Few of the small towns could be expected to provide equally expensive equipment or as large a space as the one lunch room has, but the scheme which makes this food service worthy of special note is one which could be applied anywhere.

The cafeteria is in the high school building and serves the pupils of both senior and junior high schools in addition to those in one elementary school situated some three-minutes' walk from the high school. All responsibility for the management rests with the high school home economics teacher. Two regular helpers are employed and some high school pupil labor used during the serving period. Food is sold at prices sufficiently high to meet all running costs except the time of the teacher. Each pupil pays daily for whatever food he selects, the money being collected as he leaves the serving line.

High school pupils are all served and out of the lunch room before any of the smaller children come, the session schedules having been planned with this in mind. The candy counter, which the high school students may patronize to any extent they can afford, is closed and the contents locked up before the elementary school pupils arrive. Certain dishes prepared for the older ones are not offered at all to the younger pupils (e. g., salmon wiggle, pie, and cake). All such rich foods are cleared away, completely out of sight, and the elementary school pupils have no opportunity to purchase any of them.

Approximately 75 pupils come from the grammar school, marching over with their teachers. Milk or soup is served to the small children at the tables, to avoid spilling. The older ones get their food at the cafeteria line. No elementary school child is permitted to buy any dessert whatsoever until he has either milk, cocoa, soup, or hot vegetable, and a sandwich. The desserts offered are almost entirely raw or cooked fruit and plain, hard cookies. On the day of the visit, 50 of the 75 children bought milk, 25 took soup or hot vegetable, and 50 fruit. A few children had sandwiches carried from home; the others bought them, the choice that day being between jam and peanut butter.

The method of restricting the choices of the grade school children is most admirable and is a plan which could both easily and advantageously be applied in other lunch rooms, particularly those with services comparable to that of Schoolhouse F, with its appalling preponderance of rich sweets.

The food service in Schoolhouse H, described below, is a striking example of what may be accomplished by brains and ingenuity, without much money, and its description is presented as that of a service almost ideal for the conditions under which it must operate. The lunch room occupies the top story of a six-room, six-teacher building, having 170 pupils in the first six grades, 90 of whom are furnished transportation and consequently always remain over the noon hour. The lunch room also serves some pupils from a nearby building which houses grades 7 and 8 and the high school. More than three-fourths of the elementary school children who stay at noon patronize the service, and from 100 to 115 pupils are served every school day from the first of November until the end of school in June. The service is sponsored by the school committee; stove, dishes, and other equipment bought out of school funds. The woman who manages the service pays for her own time and that of her assistant out of the proceeds of sales, in addition to meeting the entire cost of food. In view of the fact that she serves the children with excellent food at a flat rate of 15 cents per child per day, this is an achievement of no little merit.

The lunch room is light and clean and good order is maintained during the serving period. All the children come at one time and are served simultaneously. The tables are set with utensils and cold food shortly after the morning recess; hot food is served just as the children arrive. The manager and her helper do all the work, including planning and marketing, except for the work of six high school girls who help with the serving of hot food and get their own lunches free in return for this labor.

Sample menus are given below. Servings are ample and the food excellently seasoned and served with much neatness. An attempt is made never to repeat a menu in its entirety and not to repeat a highly flavored food oftener than once in two weeks. In the cold weather cocoa (two-thirds milk) is a staple; when the days are warmer, milk is served instead. Two slices of bread are always served; whole wheat bread with butter and white bread with peanut butter. The manager said the children had expressed a preference for this arrangement and she did not, therefore, attempt to vary that item in the menu.

Menu 1

Lamb stew with vegetables (potatoes, onions, carrots)
Bread
Cocoa
Orange (fresh fruit) cornstarch pudding with top milk

Menu 2

Creamed eggs on toast
Bread
Cocoa
Tapioca cream pudding

Menu 3

Beef stew with vegetables (potatoes, carrots, onions, rice)
Bread
Milk
Raisin bread pudding with top milk

Menu 4

Codfish chowder with crackers
Bread
Cocoa
Apple sauce and two plain cookies

During the school year 1927-1928 the manager of the lunch room, serving such food for 15 cents a day, not only paid for all food, for her own services and those of her assistant, but also at the end of the year had a profit of ten dollars, which was spent for additional kitchen equipment.

Mid-Session Service

In but 22 of the 800 buildings of the 222 rural Massachusetts towns considered in this report has any mid-session food service been established; and in each of these buildings it is a milk service, no attempt having been made to provide any other type of food. For 13 of the 22 buildings, the mid-session food is the only food served during the day; in 9 buildings there is in addition some sort of noon food service. In every instance the mid-session service is in the morning.

In most of these 22 schools with mid-morning milk service, no effort is made to encourage all the children to take the milk. The idea still persists that only the underweight child will profit from the extra food; and the proportion of children utilizing the service varies from 5 to 25 per cent. It is frequently very difficult to obtain good milk for serving in the isolated rural school, as the local dealers do not wish to bother with small bottles, or make deliveries at a time when the milk can be received at the schoolhouse. Sometimes there is no dealer who makes deliveries, the people depending for milk upon their own or their neighbor's cow. No school was found where this difficulty had been solved by the use of evaporated or dried milk, although this is a feasible solution.

The complaint is heard many times that mid-morning food spoils the pupils' appetites for lunch. In the towns visited, no school was seen which had a milk service at *mid-morning*. The terms "mid-session" and "mid-morning" are not synonymous. The most usual hour of breakfast of the children proved on inquiry to be seven o'clock; the noon recess is almost invariably at twelve. Mid-morning, therefore, as far as food is concerned, means half-past nine; mid-session is half-past ten. The difference of this hour is significant for appetite and digestion. In the few cases where such service exists, the usual time for drinking the milk was found to be between half-past ten and quarter of eleven. This should be expected to interfere with the noon meal. Experience elsewhere has shown that, on the contrary, a mid-morning milk service, where the children drink the milk not later than half-past nine, in no way interferes with the appetite for the noon meal. It may, rather, improve appetite through the lessening of the morning's strain and fatigue.

The amount of mid-session food service now existing in the schools of rural Massachusetts is small on any basis of computation; and the number of pupils served is negligible when estimated as a percentage of total pupils.

Summary

1. The 57,600 elementary school pupils of 222 Massachusetts towns of less than 5,000 population are housed in 800 school buildings: 370 one-room; 208 with two or three rooms; and 222 with four or more rooms.

2. Of the 16,000 children who must always remain at school over the noon hour, 6,000 attend buildings where there is no food service whatsoever.

3. Of the 800 buildings, 71 per cent have no food service; 23 per cent, supplementary service of hot food in cold weather; 3 per cent, milk service; and 3 per cent, meal service.

4. Indigestion is a leading cause of absence among school children, and a study of the records of 470 children for eight consecutive months showed a greater incidence of absence on account of stomach upsets among the pupils remaining at the schoolhouse for lunch than among those going home.

5. Data on 1,560 box lunches show that 93 per cent of the children carrying them have no hot food at noon, and only 15 per cent of the pupils bring milk.

6. The school lunch service offers many opportunities for teaching health and also for training in good manners.

7. In four-fifths of the buildings having food service, it is both sponsored and managed by the teachers.

8. When a service exists, the food is supplied (1) by the children for individual use; (2) as a contribution of material for a common hot dish; (3) by cash payment for food bought by teacher or lunch room manager; or (4) by an outside organization subsidizing the service.

9. The type of service which can be offered is limited by the physical equipment of the building, yet the examples of existing services prove that no building is too poorly equipped to make some sort of hot food service possible, at least during the winter months.

10. There is very little mid-session food service in rural Massachusetts. In only 3 per cent of the buildings was any found, and in these but a small proportion of the school population was served. In every instance, milk was the food served.

11. Mid-session feeding should always be at mid-morning, not to interfere with the noon meal, and most present practices must be revised to accomplish this.

12. Much remains to be done in establishing and improving school lunches; and with the growing tendency toward consolidation of rural schools, each year more small children will be obliged to eat their noon meal away from home.

Publication of this document approved by the
Commission on Administration and Finance

4 M—4-'30. No. 8754.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 264 June, 1930

Duration of Annual Molt in Relation to Egg Production

By F. A. Hays and Ruby Sanborn

It is generally recognized that there is a very direct relationship between egg production and the annual molt of hens. The time and duration of the molt period is therefore of economic significance to the poultry raiser. This investigation was undertaken in an attempt to more definitely determine the factors entering in this relationship.

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AGRICULTURAL EXPERIMENT STATION

AMHERST, MASS.

DURATION OF ANNUAL MOLT IN RELATION TO EGG PRODUCTION

By F. A. Hays, Research Professor of Poultry Husbandry, and
Ruby Sanborn, Research Assistant in Poultry Husbandry

Introduction

The time of onset of complete molt at the end of the pullet laying year has long been recognized as affecting pullet year egg production in a very significant manner. In flocks bred for egg production female breeders are selected with much emphasis on time of molting. Since the onset of complete molt generally marks the termination of egg production, it is evident that early molting may greatly reduce the length of the laying year. Hays and Sanborn (1927b) found the net correlation between length of the pullet laying year and annual egg production to be +.7501±.0063. Hays (1927) showed that late molting (high persistency) depends in inheritance upon a dominant gene P.

The duration of complete molt has also received considerable attention. The ideal has been a hen showing the ability to shed her feathers and to grow a new coat in the shortest time interval. Moreover, in heavy laying flocks a few individuals appear to exhibit no complete molt, and such birds generally lay continuously for two or more years. The percentage of these non-molting hens is very small, however, and there is no evidence that they are a superior group. Such individuals are separated from the normal birds in the studies reported below.

In this report consideration is given to a number of conditions which may influence duration of molt, as follows: environmental factors, such as hatching date; (2) hereditary characteristics, such as age at first egg, intensity, winter pause, broodiness, and persistency; and (3) physiological activities, such as previous egg production, 365-day production, and gain in body weight during the laying year. Finally, the relation of duration of molt to vigor and to second-year production is considered.

Character of Birds Used

This study includes all Rhode Island Red females hatched from 1917 to 1928 and kept for two full laying years. In general, they were superior to the average of the flock as judged by their pullet-year performance. The greater portion of these birds were bred for high fecundity and the remainder came from experiments designed to study broodiness, hatchability, inbreeding, and color.

The Coefficient of Correlation

The simple coefficient of correlation is used to measure the degree in which two characteristics tend to vary together. This information is valuable to poultry breeders in the selection of breeding stock and furnishes clues to possible flock improvement.

The simple correlation coefficient, calculated by the ordinary method, is a satisfactory measure only when the two characteristics being considered show true linear regression. Regression is said to be linear when the actual mean values of the dependent variable in each array of the independent variable lie in a straight line. For example, if the mean length of molt period for each of the eight hatches consistently increases or decreases at a constant rate, molt period shows linear regression on hatching date.

Each correlation table presented in this report was tested for linearity of regression first by the X^2 method of Pearson* (1924). This test may be applied to different types of distributions to determine whether departures from expectation are within the limits of normal samples. In this report a large value of X^2 indicates that deviations in length of molt period lie outside the normal correlation surface and that the correlation ratio rather than the correlation coefficient must be used to express the degree of correlation. The correlation ratio has also been calculated and the difference between the correlation coefficient and the correlation ratio tested for significance by Blakeman's (1905) method.

In biological work the significance of a simple correlation coefficient cannot safely be assumed to depend upon its absolute magnitude in all cases. This is true particularly when correlating inherited characters where there may or may not be crossing over. Interrelations between characters also complicate the situation and require the use of partial correlation methods. For purposes of selection, however, the absolute magnitude of the correlation coefficient is probably the most significant.

Among the measures of significance of correlation the method of Ezekiel (1929) is probably the most satisfactory. This method assumes that the square of the correlation coefficient measures the proportion of variance in the dependent variable that is associated with the independent variable. In other words, if $r = .30$ then $r^2 = .09$, and selection based on the independent characteristic may be expected to modify the dependent characteristic to the extent of 9 per cent in the desired direction. On this basis a simple correlation coefficient of less than .30 is of little value as a guide in selection.

Environmental Factors

1. *Hatching Date versus Length of Molt Period.*

The hatching dates of the birds used in these studies extended over a rather limited period of time, namely the 49-day period beginning March 25 and ending near the middle of May. Hatching dates were kept constant from year to year. Since date of hatching has a significant effect upon rate of growth (Hays and Sanborn, 1929) as well as upon several characteristics affecting fecundity and upon annual egg production, it is desirable to know whether it affects the duration of molt.

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*Pearson has suggested that the X^2 method, when applied to regression lines (Slutsky, 1913) gives the best fit when the theoretical standard deviation of arrays, which is equal to the standard deviation of the population multiplied by the square root of $1 - r^2$, is used as a constant. Pearson also suggests that the theoretical frequency of arrays on a Gaussian distribution might also improve the fit. Since the numbers used in the studies reported in this paper are rather large, it is believed that the actual frequency of arrays will closely approach the theoretical in most cases. The method of Slutsky (1913) for calculating the value of X^2 for each array is used, except that the theoretical standard deviation is used in all cases.

Records are available on 936 birds giving date of hatching and length of molt period at the close of the pullet laying year. Of this number, 7 birds or 0.75 per cent exhibited no complete cessation of egg production at the end of the year as is usually the case during complete molt. Unfortunately, complete records of feather change were not kept on these individuals. This group was made up only of hens showing no cessation of egg production for a period longer than seven days at the end of their pullet laying year. Therefore, all individuals ceasing to lay for eight or more days at the end of the pullet year were classed as molting birds and used in the correlation studies. In case of two periods of 30 days or more of non-production separated by a period of laying, the longer period was considered as associated with complete molt.

The calculation of the simple coefficient of correlation between duration of molt period and hatching date for the 929 molting birds gave the following constants:

Number of birds	929
Mean length of molt period—days	75.60
Molt period standard deviation—days	±30.38
Mean hatching date (Apr. 16)	4.17
Hatching date standard deviation	±2.21
Coefficient of correlation	—.0943 ± .0219
Correlation ratio	.1190

The class interval used for molt period was 10 days and for hatching date 7 days. An average period of 75 days duration without egg production characterized the molt period. The magnitude of the standard deviation in molt shows that there was wide variability in the population with respect to duration of molt. The actual range was from 8 to 197 days.

The coefficient of correlation between duration of molt and hatching date was —.0943 ± .0219. This constant has a very small absolute magnitude and, judged by criteria already referred to in this report, has no significance.

Regression of molt duration upon hatching date by the X^2 test gave a probability of .6695 of being linear. It seems justifiable to assume, therefore, that the simple coefficient of correlation was a true measure of association between length of molt and hatching date.

The correlation ratio of .1190 for molt duration to hatching date did not differ significantly from the correlation coefficient of .0943 according to Blakeman's test. The two constants squared differed by only .0053 ± .0032, which is but 1.66 times its probable error.

Inherited Characteristics

2. *Age at First Egg versus Length of Molt Period.*

Age at first egg offers a definite criterion for selecting heavy layers because early laying or early sexual maturity is correlated with high intensity and with high persistency (Hays and Sanborn, 1926 and 1927 a). Information on the relationship between age at first egg and duration of molt period would be of value to the poultry breeder. A total of 929 birds was used in these studies. Class intervals of 10 were used for classifying the birds with respect to age at first egg and duration of molt in the correlation table. The following constants were obtained:

Number of birds	929
Mean length of molt period—days	75.60
Molt period standard deviation—days	±30.38
Mean age at first egg—days	191.50
Age standard deviation—days	±21.66
Coefficient of correlation	+.2039 ± .0212
Correlation ratio	.2829

Age at first egg ranged from 140 to 319 days in the above population. The magnitude of its standard deviation also indicated marked variability, which was brought about both by inheritance and environment.

The coefficient of correlation was of such magnitude as to be insignificant by the criteria used in this report. The regression of molt duration upon age at first egg was not linear. The regression line by the X^2 method showed a probability of only .0020 of being linear. The correlation coefficient, therefore, fails to measure the correlation desired, and the correlation ratio must be employed.

The correlation ratio of molt duration to age at first egg amounted to .2829 which is below the minimum set for significance. In other words, the constant has an absolute value too small to be significant in selection. This constant differed from the correlation coefficient by 4.63 times its probable error, and is therefore the true measure of association desired.

3. *Intensity versus Length of Molt Period.*

A population of 935 with records of winter intensity and length of molt period was available for study. There were seven individuals in this group showing no molt period. Intensity was measured by the mean size of winter clutch as suggested by Hays and Sanborn (1927 a). The seven non-molting birds had a mean clutch size of 5.02, while the 928 molting birds showed a mean clutch size of 3.4. Here is a suggestion that non-molting birds tend to be intense layers. The class interval for intensity was 1.0 and that for molt 10 days. The following constants were calculated:

Number of birds	928
Mean length of molt period—days	75.53
Molt period standard deviation—days	±30.31
Mean clutch size	3.40
Clutch size standard deviation	±1.61
Coefficient of correlation	—.2399 + .0209
Correlation ratio	.3339

The mean intensity of these birds stood at a high level, but the variability for intensity was extreme as shown by its standard deviation. The actual range in clutch size extended from 1 to 15.9.

A negative coefficient of correlation of .2399 ± .0209 is not significant, for the amount of variability in length of molt period associated with intensity was equal to the square of .2399 or .0576.

The correlation ratio of length of molt to intensity was .3339 and differed perceptibly from the simple correlation coefficient. (Correlation ratio)^2—$r^2 = .0539 \pm .0097$. This difference was 5.56 times its probable error and is certainly significant. By this test the relationship between intensity and length of molt period was non-linear, and the correlation ratio of .3339, therefore, expresses the true relationship and shows that intensity and length of molt period were significantly correlated.

The regression line for length of molt period on intensity, by the X^2 method, showed no probability of being a straight line, which further confirms non-linear relationship.

4. Duration of Winter Pause versus Length of Molt Period.

The duration of winter pause is probably governed very largely by environmental influences. The possibility exists also that length of molt period may be influenced by similar reactions to environment. Records are available on 926 birds with respect to winter pause and length of molt. In this population 393 individuals showed no cessation of production as great as four days during the winter season and were, therefore, classed as non-pause birds. These non-pause birds showed a mean molt period of 71.76 days.

In correlation studies 533 pause birds were classified with respect to length of pause and duration of molt, using class intervals of 10 days in each case. The constants obtained are as follows:

Number of birds	533
Mean length of molt period—days	78.32
Molt period standard deviation—days	±31.15
Mean winter pause—days	23.73
Winter pause standard deviation—days	±15.62
Coefficient of correlation	+.2432 ± .0275

The mean length of the molt period for the winter pause birds was 78.32 days compared with 71.76 days for the non-pause birds. It seems probable, therefore, that the winter pause group was made up of birds having greater susceptibility to adverse environmental influences insofar as they affect egg production both in winter and during the molting period.

The winter pause period of non-production had an average duration of 23.73 days, with an extremely high variability as shown by the standard deviation. Its actual range extended from 4 to 113 days.

The coefficient of correlation between winter pause duration and length of molt period was +.2432 ± .0275. This constant is below the minimum of .30 adopted as significant. From the standpoint of egg production, pullets that exhibited winter pause probably were undesirably susceptible to adverse environmental influences compared with non-pause birds.

The regression of duration of molt upon length of winter pause was strictly linear. By the X^2 method the probability of linearity stood at .7468. The simple correlation coefficient is therefore a true measure of association.

5. *Total Days Broody versus Length of Molt Period.*

Of the total of 924 birds used in this study, 242 or 26.19 per cent became broody during their pullet year. The 682 individuals not manifesting broodiness the first year had an average molt period of 78.45 days.

Broodiness appeared in varying degrees in the broody population. In the broody population used in the correlation studies there was a range of from 2 or 3 days up to 170 days spent in broodiness during the first laying year. Class intervals of 10 days were used and the broody birds classified with respect to total days broody and duration of molt period. The following are the constants obtained:

Number of birds	242
Mean length of molt period—days	67.54
Molt period standard deviation—days	±29.98
Mean days broody	42.61
Days broody standard deviation	±35.53
Coefficient of correlation	—.0736 ± .0431
Correlation ratio	.2136

The mean length of the molt period in the broody population was 67.54 days, while the mean length of molt period for the non-broody population was 78.45 days. This difference is of considerable importance from the standpoint of egg production. Evidence has been discovered (Hays and Sanborn, 1927 a) to indicate that genes for broodiness and genes for high intensity show a degree of linkage, and Section 3 of this report suggests that intense layers molt in a shorter period than ordinary layers. The interrelationship of broodiness to intensity and of intensity to length of molt probably accounts for the shorter period in broody birds.

The broody population showed a mean of 42.61 days lost to production while broody during the pullet laying year. The magnitude of the standard deviation in broodiness indicates the extreme variability of the population, which was due to varying numbers of broody periods and not to variable length of broody periods.

The coefficient of correlation between total days broody and length of molt period was —.0736 ± .0431. This constant is of no significance and indicates that the length of the molt period was independent of degree of broodiness.

The correlation ratio of molt period to total days broody was .2136 which is almost three times the value of the coefficient of correlation. (Correlation ratio)$^2 - r^2 = .0402 \pm .0167$. The difference is only 2.41 times its probable error by Blakeman's test, which suggests that the difference between the correlation ratio and the correlation coefficient is not significant.

A test for linearity of regression of duration of molt on total days broody by the X^2 method gave a probability of linearity of .8766 which again suggests that the relation between length of molt period and total days broody was close enough to linearity to make the coefficient of correlation the best measure of association.

6. *Annual Persistency versus Length of Molt Period.*

Since annual persistency has been shown by Hays and Sanborn (1927 b) to be the most important single heritable characteristic affecting pullet year egg production, it is desirable to know whether persistency is related to duration of molt. The population studied consisted of 929 birds with a definite molt period and a persistency record. In the majority of cases the onset of molt marked the termination of the persistency record. There were, however, a considerable number of cases where the persistency record ended with a cessation of egg production of 30 days or more and the period of non-production associated with complete molt began after the bird had again been in production.

The correlation between annual persistency and length of molt period was made up using 15-day class intervals for persistency and 10-day class intervals for molt period. The following constants were arrived at:

Number of birds	929
Mean length of molt period—days	75.60
Molt period standard deviation—days	±30.38
Mean annual persistency—days	339.95
Persistency standard deviation—days	±36.57
Coefficient of correlation	—.2872 ± .0203
Correlation ratio	.3613

Annual persistency ranged from a minimum of 67 days to the highest possible maximum of 365 days within a single laying year. The magnitude of its standard deviation indicates that its range of variability was not greatly different from that observed in molt period. There were 809 genetically persistent birds in the population and 120 genetically non-persistent individuals (Hays, 1927). The persistent group had a mean molt period of 72.94 days, and the non-persistent group 93.50 days. This fact indicates that high physiological activity characteristic of persistent layers was associated with a reduced molt period.

The coefficient of correlation of —.2872 ± .0203 is slightly below the minimum of .30 adopted for significance in these studies. The correlation constant suggests that highly persistent or late molting hens in general seemed to require a shorter period for molting than was required by less persistent individuals.

The correlation ratio of length of molt period to persistency was .3613. By Blakeman's tests, $(.3613)^2 - (.2872)^2 = .0480 \pm .0093$. The difference between the correlation ratio and correlation coefficient is 5.16 times its probable error, which indicates that the relationship between molt and persistency was non-linear. Therefore, the correlation ratio of .3613 expreses the true relationship between these characteristics. The data here used seem to point to a significant negative correlation between length of molt period and annual persistency. The X^2 method showed a probability of only .0011 that the regression line for duration of molt on persistency was a straight line, which further confirms the value of the correlation ratio over the correlation coefficient.

Physiological Activities

7. Weight at First Egg versus Length of Molt Period.

Records are available on weight at first pullet egg and length of molt for

920 birds. These were tabulated in a correlation table giving the following constants:

Number of birds	920
Mean length of molt period—days	75.27
Molt period standard deviation—days	±29.99
Mean weight at first egg—lbs	5.36
Weight standard deviation—lbs	±.58
Coefficient of correlation	+.1457 ± .0218
Correlation ratio	.1741

The magnitude of the standard deviation in weight indicates that the birds varied rather widely in weight when they laid their first egg. The extreme range in weight was from 3.50 pounds to 7.50 pounds. Class intervals of one-half pound were used for classification.

The positive coefficient of correlation of .1457 ± .0218 is of no statistical significance according to the criteria adopted in these studies.

The correlation ratio of duration of molt to weight at first egg was also of small absolute magnitude. By Blakeman's criterion, the difference between the correlation ratio and correlation coefficient was only 2.17 times its probable error and cannot be considered as significant. This fact indicates that the relationship between duration of molt period and body weight was linear.

The regression of length of molt on body weight by the X^2 test gave a probability of linearity of .6678, when six birds weighing less than four pounds at first egg were omitted. From these facts it seems reasonable to assume that the correlation coefficient correctly measures the relationship desired, but that the correlation between duration of molt and body weight at first egg is insignificant.

8. *Gain in Weight During the Laying Year versus Length of Molt Period.*

Body weight records at the beginning and end of the pullet laying year are available on 305 birds. It is possible, therefore, to calculate the gain or loss of each individual. In the population of 305 there were 60 individuals showing either no change or a loss in weight during the laying year. This group of 60 birds had a mean molt period of 72.17 days and may be compared with the gaining group below.

A total of 245 molting birds showed a gain in weight during the pullet laying year. These birds were classified with respect to weight increase using quarter-pound class intervals, and with respect to molt using 10-day class intervals. The following constants were derived:

Number of birds	245
Mean length of molt period—days	65.23
Molt period standard deviation—days	24.88
Mean weight increase—lbs	.67
Weight increase standard deviation—lbs	±.41
Coefficient of correlation	—.1220 ± .0424
Correlation ratio	.2315

The mean length of the molt period was 65.23 days for the birds showing a weight increase, as compared with 72.17 days for the birds having no change in weight or loss of weight.

A mean weight increase of 0.67 pound was observed, but the standard deviation for weight increase indicates wide variability. The actual range for weight increase was from 0.01 pound to 2.00 pounds.

The coefficient of correlation between weight increase and length of molt period was —.1220 ± .0424. This constant is of insufficient magnitude to be of value.

The correlation ratio of length of molt period to gain in body weight was almost twice as large as the correlation coefficient. By Blakeman's test, however, the difference in the two constants was equal to only 2.37 times its probable error. This fact suggests that the relationship of the two characteristics being considered was not far from linear.

The regression of length of molt upon weight increase, when tested by the X^2 method, gave a probability of .2125 of being a straight line. In view of these facts, the correlation coefficient measures the relationship, which appears to be insignificant.

9. *Previous Production versus Length of Molt Period.*

Previous-production records include all eggs laid from the first pullet egg up to the non-productive period associated with complete molt. The length of time concerned varied from less than 12 months to as high as 14 or 15 months in some cases. Such production records represent a long period of intensive physiological activity in heavy laying birds and the intensity of this activity may affect the duration of molt.

A population of 929 birds was used in this study. Both production and duration of molt were divided into class intervals of 10. The following constants were derived from the correlation table:

Number of birds	929
Mean length of molt period—days	75.60
Molt period standard deviation—days	±30.38
Mean previous production—eggs	231.19
Previous production standard deviation—eggs	±41.30
Coefficient of correlation	—.3105 ± .0200
Correlation ratio	.3695

The mean previous production of all birds before molting was 231.19 eggs. The variability in production as measured by the standard deviation was rather wide, with a range extending from 71 to 350 eggs. This variability was no doubt enhanced by lengthening the production period beyond a full year.

The correlation ratio of molt duration to previous production was of molt period amounted to —.3105 ± .0200 and is considered significant. This constant squared (.0964) indicates, according to Ezekiel (1929), that 9.64 per cent of the variability in duration of molt may be attributed to previous production.

The correlation ratio of molt duration to previous production was of somewhat greater magnitude than the correlation coefficient. By Blakeman's test the difference between the two constants was equal to 4.72 times its probable error. The relation between the two characteristics being studied was not linear, and therefore the correlation ratio expresses the correlation desired. The X^2 test for linearity of regression showed a probability of .0501 of linearity and confirmed the Blakeman test.

10. First-Year Egg Production versus Length of Molt Period.

First-year egg production records cover a 365-day period beginning with the first pullet egg. These records were arbitrarily terminated on the 365th day regardless of whether or not the bird was laying at the time. Such egg records were significantly lower than previous-production records in highly persistent individuals. In general, first-year records are comparable with previous-production records in studying the effects of intense physiological activity of the reproductive system upon duration of molt period.

The same population of 929 birds considered in Section 9 was used to study the correlation between 365-day production and duration of molt period. Class intervals of 10 were used for both characteristics. The following constants appear in the correlation table:

Number of birds	929
Mean length of molt period—days	75.60
Molt period standard deviation—days	±30.38
Mean first-year production—eggs	223.99
Production standard deviation—eggs	±35.14
Coefficient of correlation	—.3010 ± .0201
Correlation ratio	.3592

The mean 365-day production was 224 eggs compared with a mean of 231.19 eggs produced previous to molt in the same population. The standard deviation in production was smaller on the 365-day records than on the previous-production records, as might be anticipated.

The correlation between 365-day production and length of molt period was tested for linearity, and the regression of duration of molt on egg production gave a probability of .3031 of linearity by the X^2 method.

The correlation ratio of duration of molt to 365-day production was .3592. By Blakeman's test this constant showed a difference from the correlation coefficient 4.57 times as great as the error of difference. It is probable that the regression was not linear and that the correlation ratio expresses the true correlation. The correlation between 365-day production and duration of molt was —.3592. It is a significant constant and differs but slightly from the similar constant obtained in Section 9.

Duration of Molt as a Measure of Vigor and Second-Year Production

As a measure of vigor Hays and Sanborn (1928) have made use of mortality rates for pullets during the first year of laying. Such mortality rates were calculated for each family and the families may be directly compared in this respect. The following studies were made to discover whether degree of vigor was associated with rapidity of molt.

Second-year egg production is of considerable economic importance. Birds that fail to lay heavily the second year, even though their pullet record was high, are not classed as satisfactory breeders. It is desirable, therefore, to find out whether the duration of annual molt is associated with second-year egg production.

11. Duration of Molt versus Family Mortality.

Records are available on 929 individuals showing an annual molt record. Of this number 157 came from families with no mortality in the laying houses. These 157 birds had a mean molt period of 82.25 days. Records on 772 birds from families with some mortality were tabulated against their duration of molt and the following constants derived from a correlation table:

Number of birds	772
Mean length of molt period—days	74.25
Molt period standard deviation—days	±30.19
Mean family mortality—per cent	25.35
Mortality standard deviation—per cent	±14.50
Coefficient of correlation	+.0828 ± .0241
Correlation ratio	.1898

The mean length of molt period for the group of birds from families with some mortality in the laying houses was 74.25 days as compared with a mean molt period of 82.25 days for the 157 individuals from families with no mortality. This suggests that the more vigorous birds did not molt quite as rapidly as the less vigorous.

Mean family mortality amounted to slightly over 25 per cent. The fact should be noted in this connection that no culling is done after the pullets are placed in the laying houses. Any decrease in numbers is, therefore, brought about by the death of the birds. The range in mortality rate extended from 1 to 80 per cent. Evidently the flock was far from uniform in vigor as measured by mortality rate.

The coefficient of correlation appears to be insignificant. When the regression of duration of molt period on mortality rate was tested by the X^2 method, the probability of linearity was .0915. The odds are, therefore, greater than 10 to 1 against linearity, and the simple correlation coefficient does not express the correlation desired.

The correlation ratio of duration of molt to family mortality was .1898. This differs from the coefficient by an amount 3.64 times as great as its probable error. This constant correctly expresses the relationship desired but it is of insignificant magnitude. It seems apparent that vigor and duration of molt were independent in the flock studied.

12. Duration of Molt versus Second-Year Egg Production.

A population of 541 birds furnished the records on molt duration and second-year production. The second-year egg records began the day following the close of the 365-day pullet year records and covered a period of

365 days. These studies were undertaken to discover whether the length of the molt period was a criterion of second-year production. The following constants came from the correlation table:

Number of birds	541
Mean length of molt period—days	78.45
Molt period standard deviation—days	±31.81
Mean second-year egg production	140.21
Production standard deviation	±40.95
Coefficient of correlation	—.2960 ± .0265
Correlation ratio	.3572

Mean second-year egg production ranged from 11 to 250 eggs. There existed a wide variability here such as was observed in Section 10 when pullet-year records were considered.

The coefficient of correlation was tested for linearity of regression by the X^2 method, which gave a probability of .4369 of linearity. The absolute magnitude of this constant is sufficiently close to .30 to suggest a significant negative correlation between molt duration and second year production. This correlation was in a sense false, however, because the time consumed in molting came out of the second-year production period more often than out of the pullet-year production period. It seems inadvisable, therefore, to attach very much weight to this constant.

The correlation ratio of molt duration to second-year production was higher than the coefficient of correlation. The difference between the two constants by Blakeman's test is 3.57 times the probable error of difference. It may be assumed, therefore, that the regression of molt duration upon second-year production was not linear, and that the correlation ratio expresses a significant negative relation between duration of molt and second-year egg production.

Summary

1. This report includes studies of some of the factors possibly affecting the duration of annual molt, also the relation of length of molt period to vigor and to second-year egg production. In this study 936 pedigreed Rhode Island Red hens that were trapnested for two complete laying years were used.

2. The simple correlation coefficient is used when regression is linear by the X^2 test. When regression is non-linear, the correlation ratio is employed and Blakeman's test for linearity applied.

3. Hatching date did not affect duration of complete molt.

4. Age at first egg was not significantly correlated with length of molt period.

5. Intensity showed a significant negative correlation with molt duration of .3339.

6. Length of winter pause was independent of duration of molt period.

7. Total days broody in the pullet year was independent of length of molt period.

8. Persistency showed a significant correlation of —.3613 with duration of molt.

9. Weight at first egg exhibited no relationship to duration of molt.

10. Gain in body weight during the pullet laying year was independent of molt duration.

11. Egg production previous to the molt showed a negative correlation of .3695 with length of molt, which is statistically valuable.

12. The number of eggs laid in 365 days by the pullet gave a negative correlation to molt duration of .3592, which may be considered significant.

13. Vigor did not affect duration of molt.

14. Second-year egg production was negatively correlated with length of molt to the extent of —.2960, which is probably significant.

15. All significant correlations occurred where the regression was nonlinear.

16. In general, highly intense layers and persistent layers exhibited the shortest molt period. This fact indicates that the physiological process of molting and feather growth took place at a more rapid rate in heavy layers.

References

Blakeman, J. 1905. On tests of linearity of regression in frequency distribution. Biometrika 4:332-350.

Ezekiel, M. 1929. Meaning and significance of correlation coefficients. Amer. Econ. Rev. 19:246-250.

Hays, F. A. and Ruby Sanborn. 1926. Annual persistency in relation to winter and annual egg production. Mass. Agr. Expt. Sta. Tech. Bul. 9.

Hays, F. A. and Ruby Sanborn. 1927 a. Intensity or rate of laying in relation to fecundity. Mass. Agr. Expt. Sta. Tech. Bul. 11.

Hays, F. A. and Ruby Sanborn. 1927 b. Net correlation of characters concerned in fecundity. Mass. Agr. Expt. Sta. Tech. Bul. 12.

Hays, F. A. 1927. The inheritance of persistency and its relation to fecundity. Proc. World's Poultry Congress, pp. 92-95.

Hays, F.A. and Ruby Sanborn. 1928. Vigor in production-bred flocks. Mass. Agr. Expt. Sta. Bul. 242.

Hays, F. A. and Ruby Sanborn. 1929. Rate of growth in Rhode Island Reds. Mass. Agr. Expt. Sta. Bul. 259.

Pearson, K. 1905. Mathematical contributions to the theory of evolution XIV. Cambridge University Press.

Pearson, K. 1924. Tables for statisticians and biometricians. Second edition. p. XXXII. Cambridge University Press.

Slutsky, E. 1913. On the criterion of goodness of fit of the regression lines and on the best method of fitting them to data. Jour. Roy. Statis. Soc. 77:78-84.

Publication of this document approved by the Commission on Administration and Finance

3M-6-'30. No. 9485.

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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 265 October, 1930

A Chemical Study of Cranberries

By F. W. Morse

Cape Cod cranberries have long had an enviable reputation. In order that their popularity with the consuming public may continue, it is essential that their nutritional value be known and that a high standard of quality be maintained. This investigation was undertaken in an attempt to define chemically standards of quality and nutrition in this product.

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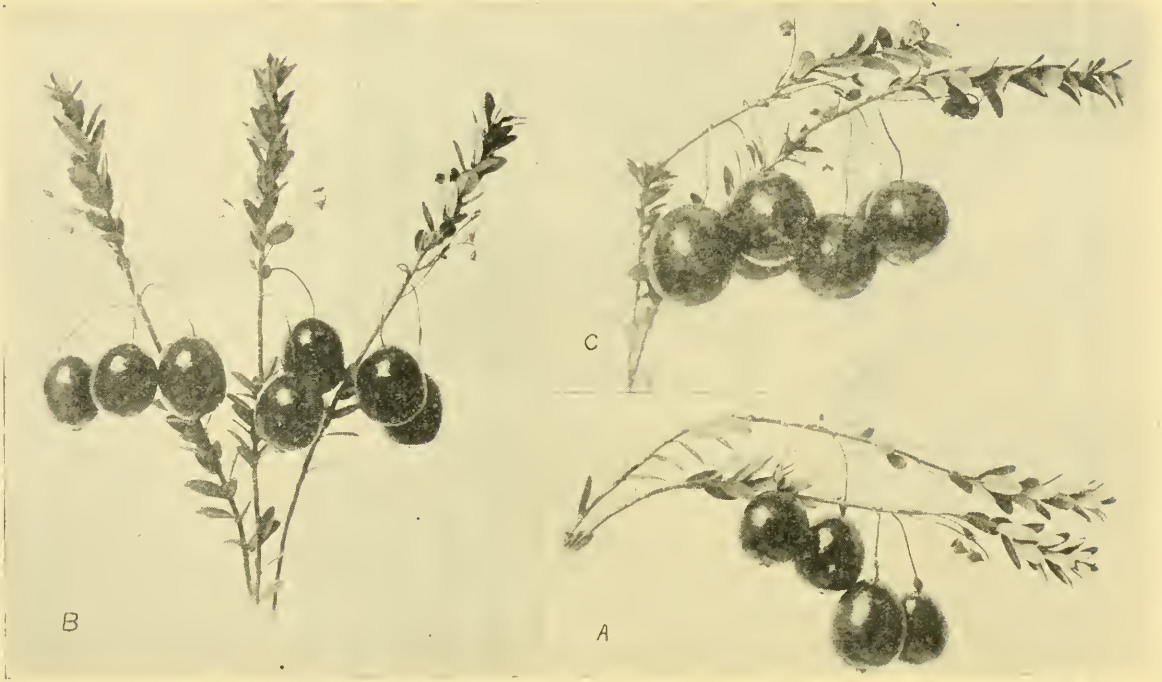

A—EARLY BLACK, the standard Early Variety and the Most Important Variety Grown.
B—HOWES, the Standard and Most Important Late Variety.
C—McFARLIN, the Leading Fancy Variety.

A CHEMICAL STUDY OF CRANBERRIES

By F. W. Morse,[1] Research Professor of Chemistry

Introduction

The value of the crop of cranberries produced in Massachusetts is around four million dollars annually. Their production, moreover, increases the value of land for the community in a striking degree. A peat swamp that is nearly worthless for farming or forestry becomes valued at one thousand dollars per acre when transformed into a cranberry bog.

Cranberries have occupied very little space in the literature of foods and nutrition. Wiley (13)[2] mentions them in a paragraph and gives a partial analysis. They are included in tables by Sherman (12) and Rose (11). Not many references to the American cranberry, *Vaccinium macrocarpum*, are to be found in the literature of chemistry, and several of them originated at this Experiment Station. European references usually mean either *Vaccinium vitis idaea or Vaccinium oxycoccus*, the Preisselbeere and Moosbeere respectively.

Griebel (6) gives two analyses of *V. macrocarpum* stated to have been grown in Germany. Bigelow and Dunbar (1) and Nelson (10) have determined the proportions of citric and malic acids occurring in cranberries. Mason (8) and several others have measured the amount of benzoic acid which they contain. Culpepper and Caldwell (5) included cranberries in their study of discoloration of canned fruit.

The chemical studies included in this article deal with the changes in composition of the fruit as the berries develop on the vines before harvesting and while held in storage for the market, and show the composition of many of the numerous varieties grown in this State, New Jersey and Wisconsin.

It is necessary to present first the studies of the ripening cranberry and of the stored fruit, since the range in composition of the varieties may be in part dependent on the maturity of the sample when picked from the vines or the length of time it was in storage.

Changes in the Composition of Cranberries during Ripening on the Vines

The two most widely grown varieties of Cape Cod cranberries, Early Black and Howes, were under observation during the ripening periods of 1926 and 1927. The berries that served for our studies were grown at the cranberry experiment station in East Wareham.

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[1] The aid of the cranberry growers who supplied samples of their product, and the financial contribution of the American Cranberry Exchange are gratefully acknowledged, and their spirit of cooperation is highly appreciated. The author also acknowledges the assistance of C. P. Jones of the Research Laboratories, who made the determinations of total sugar and starch in the samples of 1926 and 1927, and of Philip H. Smith of the Feed Control Laboratory, who supervised the fiber and protein determinations. The cooperation of the Department of Pomology by putting its cold-storage facilities at our service was an important factor in the studies.

[2] Figures in parentheses refer to literature cited on page 100.

Harvesting the Berries

The cranberries were picked at weekly intervals unless rain interfered, in which case the vines were allowed to become dry before the fruit was touched. Uniform conditions at the time of picking the berries were deemed to be more desirable than equal intervals of time between samples. The samples were sent to the laboratory at Amherst by parcel post, and about forty-eight hours elapsed between the picking and the arrival of the sample. The details of securing and forwarding samples were executed by Dr. H. J. Franklin and Mr. J. L. Kelley.

Preparation for Analysis

On arrival the cranberries were at once placed in an electric refrigerator at 40° F. The next day the samples were sorted by hand and perfect, sound berries were selected for analysis, from which charges of 500 grams were weighed and prepared for the drying-oven.

The skin of cranberries is so nearly waterproof that to promote quick drying it was necessary to cut every berry into halves before spreading them on trays in the steam-heated oven. The cut berries were dried until they were brittle enough to be easily ground to powder, which required about three days. When dry, the berries were allowed to cool in the air of the room, then weighed as air-dry material and preserved in glass-stoppered bottles for further preparation for analysis.

The air-dry material was pulverized in an iron mortar to a fine powder and returned to the bottle to be used subsequently for determinations of total sugar, starch, fiber, wax, dry matter and protein. In 1926 the air-dry material was used for determination of total acid, but it was found that in the drying some of the malic acid of the fruit must have been changed or destroyed by the heat (9). During the second season, 1927, air-dry material was prepared as usual for all determinations except total acid, which was measured in the fresh fruit as each sample arrived at the laboratory.

Description of Berries

The earliest samples of Early Black cranberries were beginning to show a little red on some of the fruit, while Howes were wholly green. Both kinds were hard and crisp when cut and their seeds were white.

As the season advanced and the berries became more and more colored they became slightly softer to touch and were more easily cut. The seeds changed from white to yellow. By the last of September the Early Black variety had the dark red tint which gives it its name. The berries cut easily and the seeds were brown and fell from the cut halves. The Howes variety at this time appeared immature, hard and crisp under the knife, with light yellow seeds. The sample of October 7, 1926 was deeply colored, cut easily and behaved much like the mature Early Black.

The chemical compositition for both seasons is shown in Tables 1 and 2.

The principal change in composition during the ripening is the progressive increase in the percentage of total sugar which is accompanied by a

TABLE 1.—COMPOSITION OF CRANBERRIES WHILE RIPENING ON VINES—1926

Date	EARLY BLACK Dry matter	 Total sugar	 Starch	HOWES Dry matter	 Total sugar	 Starch
Aug. 31	10.6	1.98	.14	10.6	1.63	.10
Sept. 2	10.5	1.85	.15	10.9	2.26	.11
Sept. 9	10.7	2.75	.14	11.2	3.05	.11
Sept. 15	11.0	2.83	.15	11.3	2.70	.15
Sept. 23	11.2	3.74	.12	12.0	3.95	.15
Sept. 29	....	....	......	12.0	3.75	.14
Oct. 7	....	....	......	12.3	4.51	.15

nearly equal gain in dry matter. The acidity of the cranberry does not vary much during the development on the vines. There are reported to be at least three acids in the cranberry, of which citric is estimated as constituting four-fifths of the total, with malic about one-fifth, while benzoic acid has never been found to reach 0.1 per cent of the fruit. So for convenience the acid is measured as though it were all citric.

The waxy substance was extracted by carbon tetrachloride and exists principally in the skin of the fruit, rendering it nearly waterproof. The figures make it appear that wax increases slightly while the fruit develops and fiber and protein decrease a trifle. When measured in percentages of air-dry matter these changes are much more pronounced and significant.

Starch constituted such an insignificant percentage of the fresh berries that it may have existed only in the seeds. The important fact is that no significant amount of sugar could be formed from starch during storage of the cranberries, and therefore the sugar in them must be formed while the berry is attached to the vine.

Recent studies by Hawkins (7) of the ripening of grapefruit have shown a decrease in acid as the fruit matures on the tree, but a marked gain in total sugar.

TABLE 2.—COMPOSITION OF CRANBERRIES WHILE RIPENING ON VINES—1927

Variety	Date	Dry matter	Total acid	Total sugar	Fiber	Wax	Protein
Early Black	September 1	10.3	2.81	2.2	1.34	.40	.45
	September 7	10.6	2.78	2.4	....	....	....
	September 15	10.9	2.81	2.9	1.30	.41	.42
	September 22	11.2	2.89	3.1	....	....	....
	September 28	11.5	2.86	3.5	1.22	.47	.40
Howes	September 1	10.5	....	1.8	1.50	.28	.34
	September 7	11.0	2.71	2.4	....	....	....
	September 15	11.4	2.73	2.9	1.43	.34	.33
	September 22	11.7	2.86	3.3	....	....	....
	September 28	11.9	2.61	3.7	1.47	.35	.31

Changes in Composition of Cranberries after Removal from the Vines

Eight varieties of cranberries were received from Dr. H. J. Franklin on October 20, 1927. There were about four quarts of each variety and the packages were placed in an electric refrigerator maintained at temperatures around 40° F. Samples of each variety were analyzed early in November for dry matter, total acids and total sugar. Four of the varieties were analyzed in January and two again in February. The varieties showed some marked variations in composition, especially in sugar percentages and also in the amount of rotten fruit, while retained in the refrigerator.

The samples were considered to be too small to represent the varieties accurately, and the study was repeated in the succeeding year. The data secured are included in Table 3.

Ten varieties were included in the study for 1928. Each variety was shipped in a standard box holding one-fourth of a barrel and the lot was received on October 20. While the first set of samples was being prepared for analysis the boxes remained in the basement of the laboratory. On October 29 they were placed in cold storage along with apples.

TABLE 3.—COMPOSITION OF CRANBERRIES WHILE IN COLD STORAGE—1927-28 and 1928-29.

Variety	Month	1927-28			1928-29		
		Dry matter	Total acid	Total sugar	Dry matter	Total acid	Total sugar
Bugle	November	13.0	2.5	3.5	12.4	2.8	3.8
	January	....	....	....	12.2	2.6	3.6
	February	13.3	2.6	3.4	12.2	2.6	3.4
	March	....	....	....	11.9	2.6	3.3
	April	....	....	....	12.0	2.5	3.4
	May	....	....	....	12.0	2.6	3.7
Centennial	November	12.8	2.1	5.2	12.2	2.3	5.2
	January	12.6	2.1	4.9	12.2	2.3	5.1
	February	....	....	....	12.0	2.2	5.0
	March	....	....	....	12.1	2.2	4.8
Centerville	November	12.5	2.2	5.2	11.9	2.2	4.6
	January	....	....	....	11.9	2.3	4.4
	February	....	....	....	12.0	2.2	4.8
Chipman	November	13.0	2.5	3.9	13.1	2.6	4.0
	January	12.6	2.3	3.4	12.9	2.5	3.4
	February	12.8	2.5	3.4	12.9	2.4	3.5
	March	....	....	....	13.0	2.4	3.6
	April	....	....	....	12.6	2.4	3.7
	May	....	....	....	13.3	2.4	4.1
Holliston	November	....	....	....	12.0	2.1	4.4
	January	....	....	....	12.0	2.3	3.5
	February	....	....	....	12.1	2.2	3.6
	March	....	....	....	11.6	2.2	3.4
McFarlin	November	....	....	....	11.9	2.3	4.1
	January	....	....	....	11.7	2.4	3.7
	February	....	....	....	11.7	2.4	3.8
	March	....	....	....	11.6	2.2	3.8
Pride	November	11.8	2.5	3.2	11.5	2.7	3.5
	January	11.6	2.4	2.7	11.4	2.6	3.4
	February	....	....	....	11.6	2.5	2.9
Randall	November	11.8	2.4	4.1	11.3	2.3	3.7
	January	11.8	2.3	4.2	11.4	2.2	3.6
	February	....	....	....	11.3	2.2	3.4
	March	....	....	....	11.2	2.1	3.5
	April	....	....	....	11.7	2.2	3.7
Shaw's Success	November	12.8	2.5	4.1	12.5	2.7	3.7
	January	....	....	....	12.4	2.5	3.6
	February	....	....	....	12.5	2.4	3.6
	March	....	....	....	12.6	2.4	3.9
Stanley	November	12.2	2.1	4.4	11.5	2.2	3.9
	January	....	....	....	12.1	2.3	3.8

Samples were taken from the boxes at monthly intervals until there had developed a proportion of rotten berries that rendered a variety useless for further storage. Total acids were always determined in the fresh sample, but dried material was used for total sugar and dry matter.

About three quarts were removed for each sample and sorted by hand. The proportions of sound and unsound berries were recorded for comparison of keeping quality of the varieties. Sorting by hand is more thorough than machine sorting as used for shipment. Berries just beginning to decay were removed by hand but such fruit would as a rule go through the machine with the sound berries.

The varieties differed considerably in their resistance to rot. To some extent this may be a varietal quality but resistance may be overcome by the presence of much disease on the bog from which the berries came. Stanley was the least resistant and was two-thirds rotten by January 10, 1929. On February 7 Holliston, McFarlin and Pride were more than half decayed, Centennial was about half spoiled, and Shaw's Success was 40 per cent bad. By March 11 Bugle and Randall were more than 40 per cent decayed, while Chipman was not over 25 per cent spoiled.

The analytical data for both series of varieties are combined in Table 3.

Centennial had distinctly the highest percentages of sugar and Centerville was next. The other eight varieties were much alike in composition.

Changes in composition during storage were most noticeable in the percentages of sugar. Every variety showed a decrease in sugar in the second sample. Centennial, Holliston and Pride continued to show a decrease until they were no longer sampled. Stanley was sampled but twice. Bugle, Chipman and Randall had a final percentage of sugar nearly as high or higher than the first percentage. This was probably due to the last samples having been stored for a month in the electric refrigerator, which has a dry atmosphere and tends to dry any material stored within it.

Centerville and Shaw's Success appeared to show selective decay of the berries making up their respective lots. Both lots showed a wide range in size of berries and to some extent variations in shape, as though the varieties were not pure strains. As decay progressed the largest berries appeared the least resistant. So it seems that there may have been a somewhat different type of fruit at the last sampling.

Holliston showed the most loss in sugar during storage, and this loss was undoubtedly due to respiration. The variety also showed a noticeable peculiarity in its decay. A large proportion of its rejected berries while soft were not rotten but had the character of smothered berries in unventilated packages. The Hollistons, however, were in a standard box with ventilated sides like the other varieties. It appears that Holliston is a variety that perhaps undergoes respiration more actively than the other varieties.

The losses of sugar are due to respiration within the berries, as shown by this Experiment Station in some earlier work. The shrinkage in acids is also due to the same cause. Furthermore, the fruit may lose water by drying if stored where there is free movement of air about them. The actual rate of shrinkage in lots of cranberries due to chemical change is difficult to measure because any given quantity of the fruit will almost surely develop some decay in a few days and render the losses of sound fruit uncertain. Losses in weight for short periods are not large enough to overcome the errors which may occur in successive weighings.

Earlier storage experiments with Early Blacks and Howes reported in Bulletin 198 of this Station showed results closely similar to those of this series.

Grapefruit in cold storage show relatively more loss of acid than of sugar (7). Apples show a shrinkage in both acid and total sugar as the storage season lengthens (2), which accounts doubtless for the gradual loss of flavor or "dead ripe" character.

Cranberries preserve their tart flavor practically unchanged during storage and the cooking quality in sound berries is maintained.

Comparison of Varieties of Cranberries in 1929

The results of the analysis of varieties of cranberries in 1928 led to the comparison of a larger number in the following year. The study was undertaken at the suggestion of Dr. Franklin, who for several years has been systematically comparing the characteristics of the named varieties of cranberries. Through his efforts, aided by Dr. N. E. Stevens of the United States Department of Agriculture, samples of 61 varieties of cranberries were received at the laboratory between October 1 and November 30, 1929, the larger part of them arriving before the close of October. The varieties were represented by 116 different samples, of which 87 were from Massachusetts, 13 from New Jersey and 16 from Wisconsin. Nearly all were shipped by express and upon arrival at the Experiment Station were placed at once in cold storage along with apples.

The samples from Massachusetts were all shipped in standard boxes holding one-fourth barrel each, and having ventilated sides. Those from a distance were generally shipped in boxes which contained several samples of 3 to 4 quarts each.

Beginning the first week in November a group of small samples was taken from the boxes in cold storage, at approximately weekly intervals, and brought to the laboratory. The sampling and analyzing were finished before the end of March, 1930. A small sample consisted of about 3 quarts and was taken from the top to the center of the box containing the variety. Each sample was sorted by hand, and the proportions of sound and unsound berries recorded for comparison of keeping qualities of the varieties.

From the sound fruit, charges were weighed for determination of total acid, total sugar and dry matter. Acid and sugar were both determined in the same charge of fresh berries by using different portions of the solution prepared from them. The charge for dry matter was cut and dried as previously described in the study of ripening.

It will be noted in scanning the data that not only are there some striking variations in composition between varieties but that when a variety is represented by several samples the composition of the different samples is far from uniform. Of the constituents determined, sugar varied most widely, and the previous studies of ripening and storage serve in some measure to explain the differences. Sugar was shown to increase from week to week until the cranberries were harvested but after removal from the vines the berries lost sugar more or less steadily during storage.

There was no control of the harvesting period for any of these variety samples. They were picked at the convenience of the grower and held until shipped to the laboratory. It was not possible to analyze the varieties simultaneously nor rapidly with regard to time. Hence both maturity and respiration were variables in the life of the cranberry and must have exerted more or less influence on the composition.

Variation due to stages of maturity is most apparent in the range of composition within a variety. This is because the differences between samples are commonly larger than those which actually have been found to be due to storage. For example, Champion was represented by three samples: one was analyzed November 27 and contained 4 per cent of sugar, two were analyzed in February and showed over 5 per cent of sugar. The low percentage of sugar must have been due to immaturity at the time of harvesting that sample.

Table 4.—Composition of cranberries—Crop of 1929.

Massachusetts Varieties

Variety	Source of sample	Date of analysis	Dry matter	Total acid	Total sugar
Atkin's Seedling....	Atkin's Bog, Pleasant Lake	Jan. 7, 1930	11.5	2.50	4.16
Aviator............	Atwood Bog Co., S. Carver	Dec. 12, 1929	13.5	2.24	4.76
Berlin Bell.........	E. C. Ellis, Bournedale	Dec. 31, 1929	11.4	2.27	4.22
Berry..............	Fuller-Hammond Co., Wareham	Nov. 4, 1929	11.9	2.10	4.08
	F. Howe, Middleboro	Nov. 15, 1929	11.3	2.19	4.75
	Federal Bog, S. Carver	Feb. 13, 1930	....	2.24	3.91
Big Red...........	R. Gibbs, S. Carver	Jan. 16, 1930	11.8	2.24	4.38
Black Veil.........	E. Atwood, S. Carver	Dec. 31, 1929	12.5	1.87	5.66
	B. Shaw, S. Carver	Jan. 16, 1930	11.7	2.11	4.00
	W. W. Benjamin Co., S. Carver	Jan. 23, 1930	12.3	1.90	4.14
Brook Farm........	F. Tindale, S. Hanson	Dec. 12, 1929	....	2.66	3.75
Buccilieu...........	Fuller-Hammond Co., Wareham	Jan. 7, 1930	13.2	2.29	5.40
	Harlow Brook Bog, Wareham	Jan. 30, 1930	12.3	2.37	4.00
Bugle..............	Atwood Bog, S. Carver	Feb. 24, 1930	....	2.29	3.33
	Roos Bog, Sandwich	Mar. 3, 1930	12.7	2.50	3.33
	Ware Bros., White Island	Mar. 3, 1930	11.6	2.37	3.00
Centennial.........	Lowell Cranberry Co.	Nov. 4, 1929	12.9	2.29	4.69
	Federal Bog, S. Carver	Jan. 30, 1930	....	1.98	5.50
	C. Maxim, N. Rochester	Jan. 30, 1930	....	2.11	5.27
	C. Weston, Middleboro	Jan. 30, 1930	....	2.03	5.19
Centerville.........	H. Gibbs, S. Carver	Dec. 3, 1929	12.6	2.32	5.45
	T. Tindale, S. Hanover	Jan. 30, 1930	....	2.24	4.66
	Vaughn Bog, S. Carver	Jan. 30, 1930	....	2.27	4.94
Champion..........	B. C. Shaw, E. Middleboro	Nov. 27, 1929	11.8	2.15	4.00
	Swift Bros., Falmouth	Feb. 6, 1930	13.1	2.11	5.45
	Vaughn Bog, S. Carver	Feb. 13, 1930	....	2.11	5.18
Chipman...........	Atwood Bog Co., S. Carver	Feb. 24, 1930	12.2	2.21	2.61
	LeB. Barker, Plymouth	Mar. 3, 1930	12.5	2.34	3.33
	S. Childs, Orleans	Mar. 3, 1930	12.8	1.93	3.87
Early Black........	Lowell Cranberry Co.	Jan. 16, 1930	12.2	2.34	4.08
	State Bog, E. Wareham	Jan. 23, 1930	11.5	2.21	3.71
	C. Vose, Marion	Jan. 23, 1930	11.8	2.54	3.09
	L. Crowell, E. Dennis	Jan. 30, 1930	....	2.48	3.29
	E. Atwood, S. Carver	Feb. 24, 1930	....	2.18	3.53
Gifford............	Weston Bog, Duxbury	Dec. 12, 1929	....	2.63	4.28
Horse Neck........	C. Vose, Marion	Dec. 31, 1929	11.9	2.53	3.63
Howes.............	State Bog, E. Wareham	Nov. 4, 1929	12.4	2.15	3.87
	E. Eldridge, Orleans	Nov. 4, 1929	13.1	2.20	4.71
	Lowell Cranberry Co.	Nov. 13, 1929	13.5	2.14	4.91
	Nantucket Cranberry Co.	Jan. 16, 1930	12.5	2.31	4.44

Table 4.—Composition of cranberries—Crop of 1929.—Continued.

Massachusetts Varieties—Concluded

Variety	Source of sample	Date of analysis	Dry matter	Total acid	Total sugar
Indian Head.......	Emerson Bog, S. Hanson	Dec. 12, 1929	....	2.53	4.14
Kelley............	Totman Bog, N. Easton	Dec. 12, 1929	12.2	2.42	3.08
Klondike..........	C. Weston, E. Middleboro	Dec. 31, 1929	11.7	2.37	4.61
Late Red..........	C. Vose, Marion	Dec. 31, 1929	12.7	2.34	4.80
	Swift's Bog, E. Falmouth	Feb. 6, 1930	12.6	2.16	3.85
	G. Allen, N. Rochester	Feb. 13, 1930	11.7	2.18	3.82
McFarlin..........	Fuller-Hammond Co., Wareham	Dec. 12, 1929	12.6	2.41	4.88
	LeB. Barker, Plymouth	Feb. 13, 1930	....	2.29	4.00
	T. Tindale, S. Hanover	Feb. 13, 1930	....	2.37	3.65
Mammoth.........	N. F. Washburn, Lakeville	Dec. 3, 1929	11.6	2.35	4.88
	Beaton & LeBaron, E. Middleboro	Feb. 6, 1930	....	2.11	3.57
	Florence Bog, E. Wareham	Feb. 6, 1930	....	2.18	4.05
Matthews..........	Urann's No. 1 Bog, S. Hanson	Jan. 7, 1930	11.6	2.37	3.88
	Florence Bog, E. Wareham	Feb. 13, 1930	11.9	2.21	3.32
	Ware Bros., Plymouth	Feb. 24, 1930	....	2.27	3.16
Middleboro........	F. Howe, Middleboro	Nov. 13, 1929	11.7	2.52	4.72
	Fuller-Hammond Co., Wareham	Jan. 30, 1930	13.0	2.34	4.24
	Starr Bog, E. Wareham	Feb. 13, 1930	....	2.24	4.75
Murdock...........	Russell Bog, S. Carver	Jan. 7, 1930	13.1	2.27	4.28
Newtown..........	J. Carlton, E. Sandwich	Feb. 6, 1930	....	2.50	3.47
Nova Scotia........	Eldridge Bog, Rochester	Nov. 4, 1929	12.7	2.07	4.68
Paradise Meadow...	R. Turner, Sharon	Jan. 7, 1930	12.9	2.53	5.00
Perry Red.........	C. Vose, Marion	Dec. 31, 1929	13.1	2.35	4.65
	Mary's Pond Bog, Marion	Feb. 6, 1930	....	2.16	3.81
	Perry's No. 1 Bog, Marion	Feb. 6, 1930	12.4	2.40	3.21
Pride..............	Federal Bog, Carver	Nov. 2, 1929	12.3	2.23	4.54
	C. Vose, Marion	Nov. 2, 1929	11.2	2.55	2.93
	State Bog, E. Wareham	Feb. 13, 1930	....	2.14	3.14
Rhode Island.......	T. Tindale, S. Hanson	Jan. 16, 1930	10.6	2.40	3.00
Round Red........	Fuller-Hammond Co., Carver	Dec. 12, 1929	13.6	2.45	3.63
Russell's Bell.......	Russell Bog, S. Carver	Dec. 12, 1929	....	2.21	4.14
Settler.............	J. Mackie, Center Carver	Dec. 12, 1929	....	2.18	4.00
Shaw's Success.....	H. Gibbs, S. Carver	Feb. 24, 1930	13.6	2.08	4.61
	A. H. Griffiths, S. Carver	Feb. 24, 1930	12.7	2.34	3.43
	L. B. Hardy, S. Wareham	Feb. 24, 1930	....	2.34	3.33
Shurtleff...........	Tweedy & Barnes, Wareham	Nov. 4, 1929	12.1	2.20	3.53
	Fuller-Hammond Co., Wareham	Feb. 6, 1930	....	2.11	5.00
Smalley Howes.....	L. Crowell, E. Dennis	Dec. 3, 1929	12.5	2.38	4.69
	Harlow Brook Bog, Wareham	Feb. 6, 1930	11.8	2.34	3.63
Smith's No. 1......	W. H. Nickerson, Chatham	Jan. 16, 1930	12.9	2.21	3.82
Stanley............	W. W. Benjamin Co., S. Carver	Nov. 27, 1929	13.6	2.22	5.35
Tom Howes........	Lowell Cranberry Co.	Jan. 7, 1930	12.7	2.40	4.36
	Hammond's Onset Bog	Jan. 23, 1930	12.6	2.16	3.63
	L. Crowell, E. Dennis	Feb. 6, 1930	....	2.48	3.33
Wales Henry.......	W. A. Andrews, N. Carver	Dec. 3, 1929	12.1	2.31	5.00
	N. F. Washburn, Lakeville	Feb. 6, 1930	11.6	2.18	3.59
	Wales Andrews Bog, E. Middleboro	Feb. 6, 1930	....	2.15	4.00

TABLE 4.—COMPOSITION OF CRANBERRIES—CROP OF 1929. Concluded.

New Jersey Varieties

Variety	Source of sample	Date of analysis	Dry matter	Total acid	Total sugar
Braddock Bell......	E. White, Chatsworth	Nov. 20, 1929	11.04	2.45	2.90
Centennial.........	R. B. Wilcox, Toms River	Nov. 27, 1929	11.90	2.07	5.00
Champion..........	R. B. Wilcox, Toms River	Nov. 27, 1929	12.15	2.10	4.16
Early Black........	R. B. Wilcox, Toms River	Jan. 23, 1930	11.36	2.31	3.33
Garwood Bell.......	H. S. Bowker, Medford	Dec. 3, 1929	11.74	2.41	2.86
Godfrey...........	E. White, Chatsworth	Nov. 20, 1929	12.51	2.71	3.77
Harold............	E. White, Chatsworth	Nov. 23, 1929	11.50	2.52	2.50
Harper-Applegate...	E. White, Chatsworth	Nov. 20, 1929	11.79	2.52	4.14
Howes.............	R. B. Wilcox, Toms River	Jan. 23, 1930	13.06	2.18	3.82
McFarlin..........	R. B. Wilcox, Toms River	Nov. 27, 1929	11.87	2.18	4.61
Paul..............	E. White, Chatsworth	Nov. 20, 1929	12.21	2.58	3.24
Woolman..........	H. S. Bowker, Medford	Dec. 3, 1929	12.91	2.07	4.80
Unnamed..........	Durrell & Co., Belleplain	Nov. 6, 1929	12.39	2.41	3.48

Wisconsin Varieties

Variety	Source of sample	Date of analysis	Dry matter	Total acid	Total sugar
Bennett's Jumbo....	A. E. Bennett, Cranmoor	Nov. 27, 1929	12.84	2.35	3.75
Berlin.............	V. Johnson, Tomah	Nov. 20, 1929	11.22	2.61	3.21
Gebhardt Beauty...	H. J. Gebhardt, Black River Falls	Dec. 12, 1929	11.16	2.61	2.45
Juneau............	C. Treat, Tomah	Dec. 12, 1929	11.30	2.70	2.79
McFarlin..........	Western Cran. Co., Ferron Park	Nov. 13, 1929	12.23	2.35	4.60
	Gaynor Cran. Co., Cranmoor	Dec. 3, 1929	11.74	2.32	4.17
	V. Johnson, Tomah	Dec. 12, 1929	11.76	2.43	4.11
Metallic Bell.......	A. E. Bennett, Cranmoor	Nov. 27, 1929	10.76	2.55	3.00
Natives............	R. Searls & Son, Hertel	Nov. 13, 1929	12.30	2.32	3.45
Natives............	Central Cran. Co., Cranmoor	Nov. 27, 1929	11.65	2.42	3.87
Natives............	C. O. Potter, Warrens...............	Nov. 20, 1929	11.91	2.55	3.16
Palmeter...........	Wetherby Cran. Co., Warrens	Nov. 20, 1929	11.42	2.35	3.41
Prolific............	A. E. Bennett, Cranmoor	Nov. 27, 1929	10.58	2.07	2.69
Searls Jumbo.......	C. L. D. Co., Phillips	Dec. 3, 1929	12.05	2.30	4.63
	J. Searls, Wisconsin Rapids	Nov. 13, 1929	11.58	2.23	4.00
	Wetherby Cran. Co., Warrens	Nov. 20, 1929	11.61	2.43	3.37

Mammoth and Matthews varied in composition more in the direction of storage losses by respiration, because their earliest analyses were the highest.

Chipman and Pride were the only varieties from Massachusetts represented by samples containing less than 3 per cent of sugar, and in each case the sample appeared immature in color as well as in chemical composition since the berries were only partially colored.

A possible cause of variation between samples of a given variety is an impure strain or mixture of varieties in a sample. When sorting the berries by hand it was sometimes noted that a sample had berries of more than one type distinguished by the shapes of berries.

Chipman from Orleans had an exceptionally low acid for the variety which should not be caused by immaturity nor by respiration. But such breaks are not unknown in a series of chemical analyses of natural products.

There were 13 varieties of cranberries received from New Jersey, each represented by one sample. As a rule these cranberries were harvested before they were much colored, or as one letter expressed it "when the berries were white." But this necessarily is while the fruit is immature, and the analytical results confirm the immaturity. Two varieties, McFarlin and Woolman, appeared well ripened both in color and in composition. Centennial, Champion, Howes and Early Black were respectively near the lower range of our Massachusetts samples in sugar content, this showing their relative immaturity. McFarlin on the other hand was near the highest figure for the variety in Massachusetts.

The Wisconsin samples represented three distinct cranberry districts, northern, central and southern. Two varieties were represented by a sample from each section, viz., McFarlin and Searl's Jumbo. It was noticeable that the percentages of sugar in these samples were highest from the northern and lowest from the southern districts. Further, the average of 6 varieties from Central Wisconsin was 3.58 and from Southern Wisconsin 3.21. Three samples were all that came from Northern Wisconsin and averaged 4.23 per cent.

Of the 42 varieties of Massachusetts cranberries 28, represented by 39 samples, contained between 3.50 and 4.50 per cent of sugar; 22 varieties, including 30 samples, contained more than 4.5 per cent sugar; 11 varieties, with 18 samples, had less than 3.5 per cent sugar, two of them containing less than 3 per cent.

For the three different states, the average composition was:

State	Varieties *Number*	Samples *Number*	Dry Matter *Per cent*	Acid *Per cent*	Sugar *Per cent*
Massachusetts	43	87	12.36	2.30	4.13
New Jersey	13	13	12.03	2.35	3.74
Wisconsin	12	16	11.63	2.41	3.54

One variety, McFarlin, was grown in all three states, and five varieties were common to Massachusetts and New Jersey. The composition characteristic of each variety was common to the different states, modified by the variable maturity of the samples when removed from the vines.

It is of interest to compare McFarlin data from the three states:

State	Samples *Number*	Acid *Per cent*	Sugar *Per cent*
Massachusetts	3	2.29-2.41	3.65-4.88
New Jersey	1	2.18	4.61
Wisconsin	3	2.32-2.43	4.11-4.60

Quality and Chemical Composition

Quality in cranberries has never been discussed in any publication that has come to the author's attention. To what extent it may be related to chemical composition is perhaps not to be defined. In apples (3), oranges

(4), and grapefruit (4), high quality is generally accompanied by a high sugar and high acid content occurring together. These two constituents do not account for the characteristic flavors but do cause the distinction between an insipid, a too tart, and a well balanced, sprightly taste.

It has not been observed that cranberries tend to increase in sugar after removal from the vines, but that this constituent develops with marked rapidity before picking as maturity, indicated by high color, is reached. On the other hand, total acid is as high in the immature fruit as at any later stage. Hence it appears that a better balance between acid and sugar is attained when the cranberry is allowed to remain on the vines until highly colored.

Howes, for example, have as a rule been harvested from the State Bog before October 1; and analyses have shown total sugar a little under 4 per cent, while the fruit has been only partially colored. Yet, whenever the variety has been left on the vines until fully colored dark red, the sugar content has advanced well above 4 per cent, with no increase in acidity. It would appear that the dark colored Howes would be superior in quality to the light colored berries usually harvested.

Assuming that quality in cranberries is indicated by content of total sugar, since acidity varies within comparatively narrow limits for all varieties, there were nine varieties of Massachusetts berries with 5 per cent or more total sugar; namely, Black Veil, Buccilieu, Centennial, Centerville, Champion, Paradise Meadow, Shurtleff, Stanley and Wales Henry. Some samples of these varieties, however, were too immature to reach this percentage. Thirteen other varieties yielded over 4.5 per cent total sugar and should be given consideration for quality. These were Aviator, Berry, Howes, Klondike, Late Red, McFarlin, Mammoth, Middleboro, Nova Scotia, Perry Red, Pride, Shaw's Success, Smalley Howes. Numerous samples of this group were below the given percentage.

Of the New Jersey varieties, Centennial came within the highest group, and McFarlin and Woolman were in the second group. From Wisconsin, the samples of McFarlin and Searl's Jumbo from the northern district were in the second group.

Resistance of Cranberries to Decay or Keeping Qualities of Varieties

The cold storage conditions for the cranberries in these studies were those for apples, since the boxes of berries were kept in one of the storage rooms used for apples by the Department of Pomology. In nearly all cases the Massachusetts and Wisconsin cranberries were sent to the laboratory without being screened; therefore, the berries had not been bruised by passing through the grading machinery as may be the case with cranberries shipped to market.

Samples of a given variety of cranberries coming from different bogs showed widely different proportions of sound fruit when the sub-samples were sorted. For sample, Centennial from one bog had not more than 15 per cent of sound fruit on January 30, while from another bog 60 per cent of the sample were good at that time. Perry Red cranberries from two different bogs had 70 per cent of sound fruit in February, but a lot from a third bog rotted rapidly and was discarded early in the winter.

Of the varieties with but one representative sample, it may be unfair to assume that early rotting signified that the variety was a poor keeper in storage. Some varieties represented by two or more samples, of which 50 per cent decayed by January 15, may be regarded as poor keepers, among which were Berry, Champion, Mammoth and Middleboro. At the other extreme, however, any sample that contained 60 per cent or more sound berries on April 1 showed the variety to be capable of resistance to rot under good conditions. The varieties coming in this group were Berlin Bell, Horse Neck, Howes, Paradise Meadow, Russell's Bell and Smaliey Howes. Howes and Smalley Howes were also represented by samples that had much less than 60 per cent sound fruit by April 1.

From Wisconsin, Bennett's Jumbo equalled these varieties in maintaining sound fruit.

New Jersey samples had either been screened or hand picked. However, Godfrey, Harold, and Paul retained about 70 per cent of sound fruit on April 1.

The relatively small number of samples retaining more than half the fruit in a sound condition at the end of winter shows the cold storage of cranberries to be a precarious undertaking as a means of extending the market for the fruit.

Summary

A study of the chemical changes occurring in cranberries while ripening on the vines was made during two seasons. Total sugar was found to increase rapidly as the berries ripen, while total acid remained nearly unchanged. Cranberries do not acquire their maximum proportion of sugar until fully ripe on the vines.

Studies of cranberries in cold storage covered two seasons and showed that they steadily lose sugar by respiration. Total acid decreases also, but at a smaller rate. While cranberries remain sound they contain enough acid to maintain their tart flavor.

In the fall of 1929 there were received from growers in Massachusetts, New Jersey and Wisconsin 116 different lots of cranberries representing 61 distinct varieties. They were analyzed for total acid, total sugar and dry matter. The range in percentages of total acid was from 1.87 to 2.71 and in percentages of total sugar from 2.45 to 5.66. Thirty-five samples contained more than 4.5 per cent of sugar, 49 were between 3.5 and 4.5 per cent, while 32 lots were under 3.5 per cent sugar. The samples lowest in sugar were, as a rule, only partly ripe when harvested.

Ten varieties resisted decay in cold storage to the extent of 60 per cent of sound berries on April 1, 1930; four varieties had all their samples fully half rotten by January 15; and the remaining varieties were in that condition by the end of February.

References

1. Bigelow, W. D. and Dunbar, P. B. The acid content of fruits. Jour. Indus. and Engin. Chem. 9:762-767. 1917.
2. Bigelow, W. D., Gore, H. C. and Howard, B. J. Studies on apples. U. S. Dept. Agr. Bur. Chem. Bul. 94:1-100. 1905.

3. Caldwell, J. S. Mean summer or optimum temperatures in relation to chemical composition in the apple. Jour. Agr. Research 36:367-389. 1928.
4. Collison, S. E. Sugar and acid in oranges and grapefruit. Fla. Agr. Expt. Sta. Bul. 115:1-24. 1913.
5. Culpepper, C. W. and Caldwell, J. S. The behavior of anthocyan pigments in canning. Jour. Agr. Research 35:107-132. 1927.
6. Griebel, C. Beitraege zur Kenntnis der chemischen Zusammensetzung der Preisselbeeren, Moosbeeren und Kranbeeren. Ztschr. Untersuch. Nahr. u. Genussmtl. 19:241-252. 1910.
7. Hawkins, L. A. A physiological study of grapefruit ripening and storage. Jour. Agr. Research 22:263-279. 1921.
8. Mason, G. C. The occurrence of benzoic acid naturally in cranberries. Jour. Amer. Chem. Soc. 27:613-614. 1905.
9. Nelson, E. K. The non-volatile acids of the pear, . . . cranberry . . . Jour. Amer. Chem. Soc. 49:1300-1302. 1927.
10. Rose, M. S. The Foundations of Nutrition. New York. 1927.
11. Sherman, H. C. Chemistry of Food and Nutrition. New York. 1927.
12. Wiley, H. W. Foods and Their Adulteration. Philadelphia. 1907.

Publications by Massachusetts Agricultural Experiment Station Reporting Cranberry Investigations

1907. Bulletin 115. Preliminary Report on Cranberry Insects, by H. J. Franklin.

1908. Bulletin 126. How to Fight Cranberry Insects, by H. J. Franklin.

1912. Annual Report (24th). Cranberry Investigations, 1910; Investigations during 1911, by H. J. Franklin. The Natural Fertility of Cranberry Bogs, by F. W. Morse.

1913. Annual Report (25th). Report of Cranberry Substation for 1912, by H. J. Franklin.

1914. Bulletin 150. Report of Cranberry Substation for 1913, by H. J. Franklin; Notes on the Water of Cranberry Bogs, by F. W. Morse.

1915. Bulletin 160. Report of Cranberry Substation for 1914, by H. J. Franklin.

1916. Bulletin 168. Report of Cranberry Substation for 1915, by H. J. Franklin.

1917. Bulletin 180. Report of the Cranberry Substation for 1916, by H. J. Franklin; Observations in Spoilage of Cranberries Due to Lack of Ventilation, by C. L. Shear, N. E. Stevens and B. A. Rudolph.

1919. Bulletin 192. Seventh Report of the Cranberry Substation, by H. J. Franklin.

1920. Bulletin 198. Studies of Cranberries During Storage: Chemical Studies, by F. W. Morse and C. P. Jones; Fungi Studies, by B. A. Rudolph and H. J. Franklin.

1921. Bulletin 206. Eighth Report of the Cranberry Substation, by H. J. Franklin.

1923. Extension Leaflet 72. Cranberry Growing in Massachusetts, by H. J. Franklin.
1928. Bulletin 239. Cape Cod Cranberry Insects, by H. J. Franklin.

Scientific Contributions

1926: No. 47. The Life History and Control of the Cranberry Weevil, *Anthonomus musculus* Say (Coleoptera; Curculionidae), by D. S. Lacroix. Jour. Econ. Ent. 19:819-829.
1926. No. 50. Cranberry Flower-Bud Investigations, by D. S. Lacroix. Jour. Agr. Research 33:355-363.
1927. No. 54. The Discoloration of Canned Cranberries, by F. W. Morse. Jour. Agr. Research 34:889-892.
1928. No. 80. The Iodine Content of Cape Cod Cranberries, by F. W. Morse. Jour. Biol. Chem. 79:409-411.
1929. No. 83. The Mineral Constituents of Cranberries, by F. W. Morse. Jour. Biol. Chem. 81:77-79.

In Cooperation with the United States Department of Agriculture

1924. Farmers Bulletin 1400. Establishing Cranberry Fields, by G. M. Darrow, H. J. Franklin and O. G. Malde.
1924. Farmers Bulletin 1401. Managing Cranberry Fields, by G. M. Darrow, H. J. Franklin and O. G. Malde.
1924. Farmers Bulletin 1402. Cranberry Harvesting and Handling, by H. J. Franklin, G. M. Darrow and O. G. Malde.

3M-10-'30. No. 394.